PHILOSOPHICAL

TRANSACTIONS

OF THE

ROYAL SOCIETY

OF

LONDON.

FOR THE YEAR MDCCCXXXIII.

PART II.

LONDON:

PRINTED BY RICHARD TAYLOR, RED LION COURT, FLEET STREET.

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CONTENTS.

XII. *Magnetical Experiments made principally in the South part of Europe and in Asia Minor, during the years* 1827 *to* 1832. *By the Rev.* GEORGE FISHER, *A.M., F.R.S.* . . . . . page 237

XIII. *Researches on the Arseniates, Phosphates, and Modifications of Phosphoric Acid. By* THOMAS GRAHAM, *Esq., M.A., F.R.S.E., Professor of Chemistry in the Andersonian University of Glasgow. Communicated by* EDWARD TURNER, *M.D., F.R.S.* 253

XIV. *On the influence of Colour on Heat and Odours. By* JAMES STARK, *M.D., of Edinburgh. Communicated by Sir* DAVID BREWSTER, *K.H., F.R.S.* 285

XV. *Experimental Researches in Electro-Magnetism and Magneto-Electricity. By the Rev.* WILLIAM RITCHIE, *LL.D., F.R.S., Professor of Natural Philosophy at the Royal Institution of Great Britain and in the University of London* 313

XVI. *On the Anatomical and Optical Structure of the crystalline Lenses of Animals, particularly that of the Cod. By Sir* DAVID BREWSTER, *LL.D., F.R.S. V.P.R.S. Ed.* 323

XVII. *On the magnetic powers of Soft Iron. By Mr.* FRANCIS WATKINS. *Communicated by* J. G. CHILDREN, *Esq., Sec. R.S.* 333

XVIII. *On Improvements in the Instruments and Methods employed in determining the direction and intensity of the Terrestrial Magnetic Force. By* S. HUNTER CHRISTIE, *Esq., M.A., F.R.S. M.C.P.S. Soc. Philom. Paris. Corresp.* 343

XIX. *Observations of Nebulæ and Clusters of Stars, made at Slough, with a*

Twenty-feet Reflector, between the years 1825 *and* 1833. *By Sir* John Frederick William Herschel, *Knt. Guelp., F.R.S.* . . . page 359

XX. *Experimental Researches in Electricity.—Fourth Series. By* Michael Faraday, *D.C.L., F.R.S. M.R.I., Fullerian Prof. Chem. Royal Institution, Corr. Memb. Royal Acad. of Sciences, Paris, Petersburgh, Florence, Copenhagen, Berlin* 507

XXI. *Experimental Researches on Atomic Weights. By* Edward Turner, *M.D., F.R.S. Lond. & Ed., Sec. G.S., Professor of Chemistry in the University of London* 523

XXII. *Note on a Paper by Dr.* John Davy, *entitled "Notice on the remains of the recent Volcano in the Mediterranean." By* Charles Daubeny, *M.D., F.R.S., Professor of Chemistry in the University of Oxford* . . 545

XXIII. *Observations of the Comet of Encke, made in June* 1832. *By* Thomas Henderson, *Esq., His Majesty's Astronomer at the Cape of Good Hope. Communicated, by Command of the Lords Commissioners of the Admiralty, by Captain* Beaufort, *R.N., F.R.S., Hydrographer to the Admiralty* 549

XXIV. *On the development of the disturbing Function, upon which depend the inequalities of the motions of the Planets, caused by their mutual attraction. By* James Ivory, *K.H., M.A., F.R.S., Instit. Reg. Sc. Paris. Corresp. et Reg. Sc. Gottin. Corresp.* 559

XXV. *On the Figures obtained by strewing Sand on Vibrating Surfaces, commonly called Acoustic Figures. By* Charles Wheatstone, *Esq. Communicated by* Michael Faraday, *Esq., D.C.L., F.R.S.* 593

XXVI. *On the Reflex Function of the Medulla Oblongata and Medulla Spinalis. By* Marshall Hall, *M.D., F.R.S. L. & E.* 635

XXVII. *On the present Situation of the Magnetic Lines of equal variation, and their Changes on the Terrestrial Surface. By* Peter Barlow, *Esq., F.R.S., Corr. Memb. Inst. France, and of the Imp. and Royal Academies of Petersburgh, Brussels* 667

XXVIII. *Experimental Researches in Electricity.—Fifth Series. By* Michael Faraday, *D.C.L., F.R.S., Fullerian Prof. Chem. Royal Institution, Corr. Memb. Royal and Imp. Acad. of Sciences, Paris, Petersburgh, Florence, Copenhagen, Berlin* 675

XXIX. *The Anatomy and Physiology of the Liver. By* Francis Kiernan, *Esq., Member of the Royal College of Surgeons, late Teacher of Anatomy. Communicated by* Joseph Henry Green, *Esq., F.R.S.* . . page 711

XXX. *Some Observations on the Economy of Molluscous Animals, and on the Structure of their Shells. By* John Edward Gray, *Esq., F.R.S.* . 771

Index . . . . . .

Appendix.

Meteorological Journal kept at the Apartments of the Royal Society, by order of the President and Council.

ERRATA.

Page 144, line 28, *for* absolvable *read* absorbable.

—— 146, —— 9, *for* or *read* on.

—— 281, *for* a terphosphate, a biphosphate, and phosphate of water, *read* a terhydrate, a bihydrate, and hydrate of phosphoric acid.

In Plate XIX. *for* p. 726. *read* p. 678.

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PHILOSOPHICAL TRANSACTIONS.

XII. *Magnetical Experiments made principally in the South part of Europe and in Asia Minor, during the years* 1827 *to* 1832. *By the Rev.* GEORGE FISHER, *A.M. F.R.S.*

Received November 3, 1832. Read January 24, 1833.

I. *Experiments to determine the relative Magnetic Forces soliciting a Magnetic Needle, suspended horizontally.*

THE forces were determined by a comparison of the number of vibrations made by several needles at each place. They were vibrated in a box, in the vertical sides of which were fixed narrow strips of glass, having on each of them a fine vertical line drawn by means of a diamond; by the coincidence or parallelism of these lines with the silk fibres by which the needles were suspended, also by making their extremities coincide with two fixed points on the bottom of the box, their horizontal position was insured. The first semi-arc of vibration was ten degrees, and the last two.

As the magnetism of needles is increased as the temperature is diminished, and vice versâ, it becomes necessary to reduce the experiments to the same standard. But since the law or relation existing between the changes of temperature and the corresponding increments and decrements of the magnetic intensity is not precisely known, and will moreover in some degree vary with the shape, size, &c. of the needles employed; it is better to avoid as much as possible the necessity of any correction, by making the experiments at nearly the same temperature.

The principal objection to the use of horizontal needles for the purpose of determining the comparative magnetic forces in the direction of the dipping

needle, arises from a knowledge of the dip being required. For although they admit of great delicacy of suspension, yet in high latitudes this objection is, for obvious reasons, insuperable, and their use inadmissible for this purpose.

The determination of the forces in the direction of the dipping needle was also effected by direct experiment, with three needles attached to an excellent dipping instrument made by Dollond. The first semi-arc of vibration in this instrument was 40°, and the last 10°; and the number of vibrations between these limits was generally about 80 with each needle. Many observers, I am aware, are in the habit of observing the vibrations of their needles in much smaller arcs, for the purpose of obtaining a greater number of vibrations, as well as making the times of vibrations approach nearer to isochronism, and thereby rendering corrections for the circular arcs less necessary. Desirable as these objects are, yet considerable experience in the use of these instruments has convinced me, that very little reliance can be placed on the vibrations of needles when the total arcs described are less than about 20°. Such, at least, has been the case with those which I have used, which have been very numerous, and of the best construction.

To those much accustomed to experiments with dipping instruments and other instruments for magnetical purposes, it may be needless to state the necessity of ascertaining by experiment, that the metal of which they are constructed exerts no assignable influence on the needle; at least such influence as may cause it to deflect from its true dipping position, or in any way affect the time of its completing a given number of vibrations. This can be readily ascertained by placing the instrument, with the centre-work removed if necessary, in a horizontal position, and by suspending within it either one of the needles belonging to it, or another of the same length, by means of a long fibre of raw silk. If it be found that the time of performing a given number of vibrations of the needle when thus placed within it, is the same as when the instrument is detached from it, we may infer that no such influence exists.

To avoid the objection arising from the influence of metal upon the needles, several dipping instruments have been constructed of late years of wood and card, some of which are of the usual form, and in others (in order that the friction which arises from the transverse axes of the needles when vibrating upon agate edges may be removed,) the needles are supported by fibres of silk,

secured at each end of the axes by means of a small hook or notch, which having the degree of tension necessary for its support, and also by an arrangement of the instrument resembling the equatorial movement of astronomical instruments, the needles are made to vibrate in any plane at pleasure. Ingenious as these contrivances are, they are subject to several inconveniences; and a very material one arises from the effects of temperature and humidity upon the frame and centre-work of the instrument. That which I had of this construction was in Levant and Siroc winds perfectly immovable from this cause; which, together with the effect of torsion, rendered it little better than useless for the general purposes of a dipping instrument; and I could confirm these objections by the testimony and experience of an indefatigable observer employed on the coast of Africa.

I have been led to these remarks by having witnessed a considerable degree of disappointment expressed by several persons, who in visiting foreign countries have laudably endeavoured by their exertions to add somewhat to the present stock of information upon this subject, and who have found upon their return, that they have in a great measure failed in their endeavours, either from some imperfection in the construction of their instruments, or in the methods of using them: and I cannot but consider, that an unqualified commendation of any instrument whatever, intended for foreign service, particularly for those places which, from many circumstances, can rarely be visited, without thoroughly examining its merits, to be productive of considerable mischief; since it is not only the cause of error, but tends to damp that zeal for the interests of science which travellers have it often in their power to promote.

As experiments of this nature are most frequently made at some of the principal sea-ports immediately before the embarkation of the needles, and at the same places upon their return, in order that the intervals of time may be as short as possible, which is desirable on account of the great variations which their intensities are subject to from rust and other causes; and as other experiments have generally been referred to London, it becomes necessary to know the relative forces between these places, that the requisite reductions may be made. For this purpose a series of experiments were made during the last summer by Captain Sir Everard Home, Bart. F.R.S. near London, and at South Sea Castle near Portsmouth. With a similar view, another series had

been previously made by myself at London and at Ryde (four miles from South Sea Castle) in 1830. The mean between both results is probably nearest the truth; from which the horizontal force at London is to the same at Portsmouth as 1 to 1·01755; and the forces in the direction of the dipping needle, as 1 to 1·00416. The dip at each place being 69° 40′ and 69° 23′ respectively.

Had the needles maintained precisely the same degree of magnetism during the whole period of these experiments, the forces might be at once obtained by comparing those made at each place with corresponding ones made in London; but as this was not the case, and moreover from the causes just mentioned will seldom happen in long voyages, it was necessary in this case to compare the experiments made at Gibraltar with those made at Lisbon; and also those made in the various places in the Mediterranean and Asia Minor with corresponding ones at Malta, obtained by means of short runs from this latter place. It is necessary to mention this, since by otherwise combining the experiments different results may be obtained, without attending to this circumstance.

Table I. contains the comparative horizontal forces by a mean of four needles at each place, with a small correction applied for difference of temperature. The last column of this Table contains the same, taking the horizontal force at London equal to unity. Table II. contains the comparative forces in the direction of the dipping needle determined by the experiments made with the horizontal ones; and also the results obtained by direct experiment with the dipping needles. The detail of the latter is omitted, since they are of less authority than the others, in consequence of their poles being constantly inverted for the purpose of obtaining the dip; for though their magnetism was not interfered with between the consecutive experiments, there was not that satisfactory evidence respecting any alteration in their intensities that possibly might have occurred during the intervals which is desirable: the means of both methods are therefore omitted, as the results would be vitiated by the same cause.

The dips contained in the column for that purpose, are the mean results obtained with three needles;—that at Malta, by a long series of experiments made in the years 1828-9: these were made, not only for the purpose of determining the dip with all possible precision, since the greater number of the experiments made in other parts were necessarily compared with those made

at this place, but also for the sake of comparing the dip obtained by the different methods of vibration with that obtained in the usual way. The experiments at Malta are given at the end of this paper. In each of these experiments the poles are inverted; a precaution as essential in determining the dip by the methods of vibrations as in any other method.

II. *Experiments on the diurnal variation in the intensity of the Force soliciting a Magnetic Needle, suspended horizontally at Malta.*

These experiments were first commenced on the 27th of November 1828, with the horizontal needle No. 4. used in the foregoing observations, and having the usual silk suspension. It was firmly fixed on a strong table constructed for the purpose, and placed in the centre of a large stone room in Valette, beyond the direct influence of the sun's rays, and was vibrated in the box to which it was fitted. The first semi-arc of vibration was 10°, and the last 2°; and the time of completing one hundred vibrations was obtained by proportion. The times of commencing the 1st, 3rd, and 5th vibrations, also the corresponding ones at the end of the experiment, were observed as before with a chronometer; by which three intervals were obtained in the same experiment, and a mean of them taken for the result.

The experiments were continued without intermission until the 24th of January following, when I found upon examination, that I was unable to trace the least appearance of any progression in the results, as indicating a maximum or minimum, or indeed any change whatever, excepting what appeared to be the errors of experiment: still I was induced to continue them until I had completed three hundred sets of vibrations at different periods of the day and night, in hopes, that having made so great a number of experiments, and by taking a mean of all those made about the same time, the small errors of observation would be so far eliminated as to indicate some result of this kind. In this I was again disappointed, as many of these means were nearly identical, that is, to the nearest tenth of a second. It was evident, therefore, that the daily change of intensity, if any existed, was so exceedingly small as not to be apparent in experiments with this needle, much less the periods of maximum and minimum.

On the 25th of March following, I began another series for the third time,

with a much larger needle (one belonging to the dipping instrument), and suspended by a single fibre of raw silk eighteen inches in length; the first semi-arc of vibration was reduced to 5°, and the last semi-arc to 2°; and between these limits the number of vibrations was about two hundred and thirty. In these the commencement of the 1st and every odd vibration to the 29th inclusive, were observed; and at the end of the experiments, the commencement of the 201st, 203rd, &c. to the 229th inclusive: by this means, the time of completing two hundred vibrations was obtained by a mean of fifteen independent observations.

In these, as in the former ones, very little progression appears in any one day's experiments. The differences indeed are so exceeding small, as to render them in some degree a test of the regular going of the chronometer. I will not, however, attempt to assign the degree of accuracy to which a chronometer will measure so small an interval, but merely observe, that every precaution was taken to insure accuracy, by using alternately one of three chronometers by ARNOLD; which were wound up at different periods of the day. A very small correction for the daily rate of each was applied. In one of them, which had the largest rate ($-12''$), the correction of the measured interval amounted to only one tenth of a second. The following are the mean results, taken as before, about the same period of the day.

Time.	Time of 200 Vibrations.	Therm. Fahr.	No. of Experiments.
h m	″	°	
2 20 A.M.	855·68	65·7	6
8 0	855·27	65·1	18
10 30	855·02	65·4	11
0 30 P.M.	855·15	65·8	11
2 30	854·86	67·3	13
6 0	855·28	67·0	12
10 0	855·58	65·6	11

In these observations, although they do not amount to more than one third the number of the former ones, yet when thus taken in groups, there appears in the means a regularity which was not visible in the former ones. From these it appears that the least horizontal intensity took place about 2^h A.M., and the greatest about 2^h P.M., in April and May 1829. The variation is so very minute, that I offer this conclusion with some diffidence, though I

but little doubt that it will be confirmed by the subsequent experiments of others. I regret that my own were not more extensive.

I have now to mention a source of irregularity which may possibly arise during a series of experiments of this nature, and materially vitiate the results; that is, storms of thunder and lightning. They cause, as far as my experience goes, in general, a diminution in the magnetic intensity of the needles. The observations just mentioned are fortunately exempt from this, from a continuance of fine weather during the experiments.

I had reason on several occasions to suspect this, but as I never had corresponding experiments made immediately previous to a violent storm, to compare with similar ones made subsequently, I was unable to assign with accuracy the period at which this diminution took place, and thereby identify the cause. A violent storm which took place at Malta on the 7th of December 1829, attended with considerable mischief, afforded me this opportunity. I had fortunately, the day before, made a great number of observations with all the needles, for the sake of a comparison with similar ones that I intended to make in other parts of the Mediterranean to which I was about to proceed. I availed myself therefore of the opportunity of ascertaining, during the storm, the effect produced upon the needles. In the results which were obtained, it appears that all of them were affected in a similar way, that is, they all suffered a permanent diminution of their intensities.

III. *On the diurnal Oscillations in the direction of a Magnetic Needle, suspended horizontally at Malta.*

The needle employed in these experiments was twelve inches in length. Every precaution was taken to avoid the influence of iron; and to secure the whole apparatus from damp, and to equalize the temperature around it, it was fixed, and the needle adjusted within it, six weeks before an observation was registered.

The radius of the arc described by the needle was increased from six to ten inches by light pieces of cedar attached to each end of it, and carrying upon their extremities small pieces of ivory, extending to about 4° of arc, and subdivided to every 5′. Opposite to each end of these divided extremities, were

placed three vertical hairs, at the distance of 1° apart, and as near to them as could be without touching them. The coincidence of these vertical lines, with the divisions on the white ground of the ivory behind, was observed with extreme distinctness by means of a compound microscope. By this means, the subdivisions of 5′ were again subdivided to single minutes, and by a mean of the six (which constituted an observation), to within a few seconds.

The observations were commenced on the 5th of January 1829, and carried on every hour, from 9^h A.M. to 4^h P.M., to the 21st of the same month: during this period a maximum occurred in the westerly variation, at $0^h\ 30^m$ P.M. nearly. They were recommenced on the 24th of March following, and continued until the 31st, and the needle observed every half-hour, with a few exceptions, from 7^h A.M. to 4^h P.M.; during this interval, the maximum occurred at about $1^h\ 30^m$ P.M., and the minimum at $9^h\ 30^m$ A.M. These results are obtained by taking the means of all the observations made at the same hour, and considering these means as representing the true variation at those hours. They are contained in a Table at the end of the paper. On the 1st of April, another series was commenced, and continued to the 15th. They were made from 7^h A.M. to $4^h\ 30^m$ P.M., every half-hour, and as frequently during the night as could conveniently be done, considering the great labour and want of rest attending experiments of this nature, particularly as they were accompanied by corresponding observations of the times of vibration of another needle.

From these it appears that the maximum westerly variation takes place about $1^h\ 45^m$ P.M.; from this period of the day, it gradually diminishes until about $10^h\ 0^m$ P.M.; from about this time to about sun-rise, it is nearly stationary; after this period a still further diminution takes place, and the minimum westerly variation happens at about $8^h\ 45^m$ A.M., when it again increases to about $1^h\ 45^m$ P.M., and reaches its maximum as before.

The difference between the mean maximum and minimum variation, or the mean amount of the diurnal movement of the needle, in April, was 10′ 12″.

During these observations, several oscillations, or tremulous motions in the needle were observed; and as they are occasionally registered by others, I mention three days on which they were most apparent. January 15, 1829, at $10^h\ 30^m$ A.M., the north end of the needle moved to the westward about 2′ 15″ in ten minutes; the needle exceedingly tremulous; from this period of the

day, it moved gradually back to the eastward until 3 P.M., when it again moved suddenly 2′ to the westward, and shortly afterwards back again to the eastward. The mean variation on this day was less than usual. On the 26th of March 1829, at 3^h P.M., the needle was very tremulous, and on the 29th following, at 8^h and 9^h P.M., oscillated considerably.

IV. *Experiments on the bases and edges of the craters of Vesuvius and Etna, and also on Gibraltar Rock and the neutral ground below.*

It has been observed by Baron HUMBOLDT, in describing his experiments to determine the magnet dip, that the heights of the places of observation seem to have a sensible influence on the results; and moreover, that the magnetic forces appear to be modified by the proximity of lavas. He found at Cumaná, the capital of New Andalusia, that the dip before the earthquake was invariably 43°·65 (cent. div.); but he was astonished to find three days after the violent shocks of earthquake, that it was no more than 42°·75, and a year afterwards still 42°·80, although the intensity of the magnetic forces had not varied the whole time.

With respect to the influence of height, he observes that BORDA is the only traveller who has compared in an accurate manner the dip at Santa Cruz with that determined at the top of the Peak of Teneriffe*, where he found it greater than at the bottom, which result Baron HUMBOLDT observes was exactly conformable to what he has several times obtained among the Andes; and he suggests, that it probably depends upon some system of local attraction.

* It appears also from a manuscript account of BORDA's voyage to the Canaries, that he found the card attached to his horizontal needle made a given number of vibrations in 97″ at the summit of the Peak, while at Santa Cruz (bearing E. 29° N.) it was 94″, indicating a less intensity on the summit than at the bottom. At the brink of the crater, he observed the westerly variation to be 19° 40′; at Santa Cruz 15° 50′; and at Gomera 15° 45′; which observations indicate a considerable deflection of the needle from the magnetic meridian, arising from some disturbing force.

HANSTEEN found the force soliciting a needle on the top of the round tower at Copenhagen, at the height of one hundred and twenty-six feet, to be much less than in a garden below, which he ascribes to polarity in the building. Similar experiments made at the Pagoda at Kew (which is a brick building of the same height,) by Professor RIGAUD, Sir EVERARD HOME, Bart., and myself, give no such result, nor indicate any assignable difference, either in the dip or in the magnetic force, whether observed on the top or at the bottom.

From whatever cause these differences proceed, whether from the attraction of lavas containing iron ores, from the influence of height alone, or from both causes conjointly; it is evident, that while such extraordinary discrepancies exist, either in the direction of the needle, or in the intensity of the force soliciting it, it will be impossible to reconcile the results of magnetical experiments by means of mathematical formulæ.

With a view of observing these anomalies in experiments of this nature, as well as to gratify my own curiosity, I was induced to make similar ones on Vesuvius, Etna, and Gibraltar Rock. The experiments at Vesuvius indicate a remarkable difference in the variation, observed on the top and at the bottom.

By the sun's azimuth at the crater, variation	12° 19′ W.
By the bearing of St. Francazzo at the crater, variation .	12 5½
——— Arcera at the crater, variation . . .	12 51½
Mean variation at the crater	12 25½

By a great number of observations in the neighbourhood of Baia and Naples, the westerly variation, by the same instrument, was 15° 20½′, differing 3° from that observed on the crater at the height of 3400 feet.

The magnetic force on the western edge of the crater was the same as that observed at Naples. That observed half-way up the mountain, at the hermitage on the west side, was a little less.

On the south-eastern edge of the crater of Etna, at the height of 11,000 feet, the westerly variation, by means of the sun's azimuth, was 18° 35′ west. At Catania, on the southern foot of the mountain, it was 16° 28′; and at Messina, on the north-eastern side, it was 17° 12′, with the same instrument.

The magnetic force on the crater of Etna was much greater than either at Catania or at Messina, both with a horizontal needle, and one in the direction of the dipping needle.

At Gibraltar, the experiments on the summit, at the height of 1300 feet, indicate a greater intensity than on the neutral ground below; though one of the needles, probably from some error of observation, appeared to give discordant results. The different periods of vibration are given with the other experiments, in a Table, at the end of the paper.

Upon reviewing the observations made in different parts of the Mediterranean, contained in this paper, a great irregularity will be seen in the numerical results. In proceeding from Malta to Naples, by way of Etna and Messina, it appears that an increase of the whole magnetic force took place in the first half of the distance, which we might have expected; but from Messina to Vesuvius and Naples, a considerable diminution of the intensity was observed; whereas, from their relative geographical positions, we might have concluded otherwise. Upon the whole, as we proceed eastward as far as Constantinople, there appears to be a decrease in the intensities at places having the same dip, similar to what has been observed in the western hemisphere, if we except the observations at Naples and Vesuvius.

Whether these irregularities arise from any inequalities in the distribution of the terrestrial magnetism, or from any active agency of a volcanic nature, I dare hardly venture an opinion. The deflections or deviations of the needle from the magnetic meridian, on the summits of Vesuvius and Etna, confirm the latter idea; although, on the other hand, experiments made in several places in the neighbourhood of Vesuvius, from their near agreement with each other, indicate nothing of the kind.

It will not, however, appear very extraordinary that volcanic products should exert considerable influence on the needle, when we consider how very generally iron ores enter into the composition of the different lavas. Upon submitting each specimen contained in a collection of lavas (made by SALVADORE, the Vesuvian guide,) to a light needle, suspended by a fibre of silk, I found that sixty-eight out of one hundred and twenty-four specimens exerted considerable influence upon it; most of them attracting each end indiscriminately, while others had decisive features of distinct polarity. Whether the difference between the intensity on the summit of Etna and that observed below, proceeds from the same cause, or from the influence of height alone, is alike difficult to determine.

Table A.

Experiments to determine the dip at Malta by the usual method.

The results with the poles inverted are connected with the others by brackets.

Needle, No. 1.			Needle, No. 2.			Needle, No. 3.		
Date.	Dip, each 12 Observations.	Means.	Date.	Dip, each 12 Observations.	Means.	Date.	Dip, each 12 Observations.	Means.
1828.	° ′ ″	° ′ ″	1828.	° ′ ″	° ′ ″	1828.	° ′ ″	° ′ ″
Nov. 7.	53 25 30	55 12 37	Nov. 7.	58 48 15	55 48 15	Nov. 8.	50 31 30	53 27 7
	56 59 45			52 48 15			56 22 45	
11.	56 42 45	54 57 52	11.	52 59 30	54 15 22	10.	56 10 30	54 6 15
	53 13 0			55 31 15			52 2 0	
1829.								
Jan. 24.	56 39 0	54 49 0	Dec. 31.	56 2 15	54 29 37	Dec. 10.	51 57 15	53 55 0
	52 59 0			52 57 0			55 52 45	
Mar. 6.	52 26 0	54 16 0		55 49 0	54 18 0	30.	52 7 0	54 0 0
	56 6 0			52 47 0			55 53 0	
			1829.			1829.		
7.	56 21 0	54 25 0	Mar. 7.	52 19 0	53 52 0	Mar. 6.	51 37 20	53 37 20
	52 29 0			55 25 0			55 37 20	
Mean		54 44 6	Mean		54 32 39	Mean		53 49 10
Mean of the three Needles ....54° 21′ 58″.								

Table B.

Experiments to determine the dip at Malta.

Date.	Time of 100 Vibrations in Meridian (t).	Time of 100 Vibrations perpendicular to Meridian (t').	Dip (Δ).	Means.	Needle.
	″	″	° ′	° ′ ″	
1829. Jan. 1.	147·6	161·63	56 50	54 44 30	No. 3
	151·7	170·15	52 39		
3.	162·5	184·1	51 11	53 14 0	2
	156·45	172·57	55 17		
14.	150·4	163·65	57 38	55 29 30	3
	151·4	169·02	53 21		
24.	154·65	178·02	49 0	52 23 0	1
	151·57	166·7	55 46		
Mar. 5.	157·0	173·82	54 41	53 27 0	2
	153·87	173·07	52 13		
6.	154·75	171·25	54 45	52 59 30	1
	161·07	182·4	51 14		
Mean of the three Needles.....				53 42 55	
Formula employed.... $\sin \Delta = \left(\frac{t}{t'}\right)^2$					

Table C.

Experiments to determine the dip at Malta.

Date.	Time of 100 Vibrations in Meridian (t).	Time of 100 Vibrations, horizontal (h).	Dip (Δ).	Means.	Needles.
	″	″	° ′	° ′ ″	
1829. Jan. 1.	156·6	200·8	52 32	54 24 30	No. 3
	147·3	197·7	56 17		
3.	156·45	211·95	56 59	55 14 0	2
	159·25	206·45	53 29		
14.	151·4	196·16	53 26	54 56 30	3
	145·7	195·98	56 27		
27.	155·4	201·65	53 34	54 45 0	1
	148·48	198·4	55 56		
Mar. 5.	157·0	208·25	55 22	54 30 0	2
	153·87	197·5	52 38		
6.	154·75	206·5	55 50	53 58 30	1
	161·07	205·55	52 7		
Mean of the three Needles				54 38 5	
Formula employed.... $\text{Cos}\,\Delta = \left(\frac{t}{h}\right)^2$					

Table D.

Experiments to determine the dip at Malta.

Date.	Time of 100 Vibrations perpendicular to Meridian (t').	Time of 100 Vibrations, horizontal (h).	Dip (Δ).	Means.	Needles.
	″	″	° ′	° ′ ″	
1829. Jan. 14.	169·02	196·16	53 25	54 46 0	No. 3
	160·62	195·98	56 7		
16.	181·0	208·85	53 5	54 19 0	2
	168·15	203·0	55 33		
22.	161·97	198·8	56 25	54 26 0	3
	173·5	197·9	52 27		
23.	176·47	205·25	53 32	54 40 0	2
	172·9	209·7	55 48		
28.	163·85	199·7	56 3	54 34 30	1
	169·25	195·15	53 3		
Mar. 5.	173·82	208·25	55 8	53 48 30	2
	173·07	197·5	52 29		
	171·25	206·5	55 29	53 38 0	1
	182·4	205·55	51 47		
Mean of the three Needles				54 18 51	
Formula employed.... $\text{Tan}\,\Delta = \left(\frac{h}{t'}\right)^2$					

Table E.

Places and Dates.		Time of 100 horizontal Vibrations, with				Comparative horizontal Forces.	
		Needle No. 1.	Needle No. 2.	Needle No. 3.	Needle No. 4.	Between the places connected by brackets.	Assuming force London equal to Unity.
London ..... 1827–8.	61	266·4	238·7	243·0	195·0	1·0000	1·0000
Lisbon ..... ——	61	239·7	215·7	219·7	177·3	1·2232	1·2232
* —— ..... 1831–2.	66	294·9	313·35	279·68	275·77	1·2761	1·2985 Mean 1·2608
Portsmouth ..... ——	65	333·67	352·7	314·85	313·22	1·0000	
Lisbon ..... 1828.	61½	238·9	215·8	219·7	176·8	1·0000	
Gibraltar ..... ——	68	235·5	212·0	215·0	172·0	1·0424	1·3143
——, summit .. ——	70	231·75	208·25	212·4	173·25	1·0621	1·3391
Portsmouth ..... ——	61½	268·6	239·8	242·6	196·9	1·0000	
Malta ..... ——	63	220·1	196·9	202·2	160·6	1·4788	1·5047 Mean 1·5071
—— ..... 1830.	60	227·2	201·3	206·5	167·0	1·4835	1·5095
Portsmouth ..... ——	64	276·3	244·5·	252·5	203·5	1·0000	
*Malta ..... 1829.	59	218·5	195·0	199·02	161·27	1·0000	
Messina ..... ——	51	220·1	196·5	201·1	161·25	0·9844	1·4836
Naples ..... ——	46	232·7	207·6	212·5	171·5	0·8779	1·3231
Vesuvius, half-way up ——	48	....	....	....	172·5	0·8670	1·3067
——, edge of crater ——	18	....	....	....	170·6	0·8781	1·3234
Baia ..... ——	66	235·9	210·5	216·3	173·5	0·8591	1·2947
*Malta ..... ——	64½	218·75	....	....	....	1·0000	
Syracuse ..... ——	67½	221·54	....	....	....	0·9760	1·4709
Catania ..... ——	70	225·65	....	....	....	0·9413	1·4186
Etna, summit ..... ——	32	216·75	....	....	....	1·0074	1·5181
*Malta ..... ——	68	221·5	197·95	201·62	163·05	1·0000	
Vourla ..... ——	70	223·55	199·5	203·32	164·41	0·9833	1·4819
Constantinople .... ——	72	227·5	202·95	207·1	167·5	0·9487	1·4298
Egina and Athens .. ——	78	225·5	200·5	205·1	165·5	0·9691	1·4605
Plains of Troy ..... ——	79	229·0	204·0	209·1	169·0	0·9346	1·4085

* The experiments marked * are means between the periods of vibration observed *before* and *after* those made at the places with which they are compared and bracketed with.

Table F.

Places.	Lat. N.	Long.	Variation W.	Dip.	Comparative horizontal Forces.	Comparative whole Forces.	Remarks.
London	51 30	0 9W.	....	69 40	1·0000	1·0000	
Portsmouth	50 47	1 5	....	69 23	1·0175	1·0042	
Lisbon	38 42	9 10	22 23	63 30	1·2608	0·9819	Whole force with dipping needles = 0·9426.
Gibraltar	36 5	5 4	....	60 49	1·3143	0·9366	
———, summit	——	——	....	.....	1·3391	.....	Height, 1300 feet.
Malta	35 54	14 29E.	15 15	54 17⅓	1·5071	0·8972	Whole force with dipping needles = 0·9113.
Messina	38 12	15 30	17 12	56 29½	1·4836	0·9338	
Naples	40 53	14 15	15 20	58 28½	1·3231	0·8792	
Vesuvius, half-way up W. side	40 49	14 26	....	.....	1·3067	.....	Height, 1900 feet.
———, W. edge of crater	——	——	12 25	.....	1·3234	.....	Height, 3400 feet.
Baia	40 50	14 5	15 20	.....	1·2947		
Syracuse	37 3	15 10	16 40	.....	1·4709		
Catania	37 30	15 5	16 28	.....	1·4186		
Etna, summit	37 44	15 0	18 35	.....	1·5181	.....	Height, 11,000 feet.
Vourla, near Smyrna	38 24	26 38	10 36	54 34	1·4819	0·8882	Whole force with dipping needles = 0·9152.
Egina and Athens	37 48	23 32	....	.....	1·4605		
Plains of Troy	39 51	26 7	....	.....	1·4085		
Constantinople	41 2	28 54	....	56 18	1·4298	0·8954	

Table G.

Mean westerly variation of the Needle at different hours of the day, at the Island of Malta, 1829.

Time.	January.		March.		April.	
	Variation.	No. of Obs.	Variation.	No. of Obs.	Variation.	No. of Obs.
h m	° ′ ″		° ′ ″		° ′ ″	
1 0 A.M.	.....	.....	14 60 15	2	14 51 19	4
2 0	.....	.....	58 0	2	51 27	5
4 0	.....	.....	58 0	2	51 30	2
5 0	.....	.....	59 45	2	50 7	2
7 0	.....	.....	59 12	7	50 30	11
7 30	.....	.....	59 5	7	49 38	9
8 0	.....	.....	58 52	7	50 25	4
8 30	.....	.....	58 42	7	47 15	3
9 0	14 34 46	11	58 40	9	48 14	11
9 30	35 3	11	58 33	9	49 3	11
10 0	35 19	11	58 42	9	50 30	11
10 30	35 33	11	58 45	9	52 19	11
11 0	35 48	11	59 15	9	53 46	11
11 30	36 9	11	59 28	8	55 10	13
Noon.	36 20	11	59 50	9	55 55	12
0 30	36 16	11	59 55	9	57 16	10
1 0	36 10	11	60 5	9	57 49	8
1 30	35 53	11	60 8	9	57 36	10
2 0	34 50	11	60 3	9	58 12	12
2 30	34 24	11	59 53	9	57 7	9
3 0	34 9	11	59 53	9	55 48	9
3 30	34 1	11	59 45	9	54 49	8
4 0	33 44	11	59 30	9	53 40	10
7 30	.....	.....	.....	9	52 45	3
8 0	.....	.....	.....	9	52 30	2
8 30	.....	.....	.....	9	53 0	3
9 0	.....	.....	59 4	2	52 41	5
9 30	.....	.....	59 22	2	51 40	5
10 0	.....	.....	59 22	2	51 56	5
Midnight.	.....	.....	60 0	2	51 30	4
	Maximum at about 0h 30m P.M. Minimum ——— ?		Maximum at about 1h 30m P.M. Minimum ——— 9 30 A.M.		Maximum at about 1h 45m P.M. Minimum ——— 8 45 A.M.	

XIII. *Researches on the Arseniates, Phosphates, and Modifications of Phosphoric Acid.* *By* THOMAS GRAHAM, *Esq. M.A. F.R.S.E. Professor of Chemistry in the Andersonian University of Glasgow. Communicated by* EDWARD TURNER, *M.D. F.R.S. &c.*

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I. *Of the Subsalts.*

NO classes of salts have more liberally rewarded investigation than the arseniates and the phosphates. Witness the discovery of the extraordinary phosphates of lime by BERZELIUS; the observation of the identity of form of the corresponding arseniates and phosphates by MITSCHERLICH, and the doctrine of isomorphism to which that observation led; the discovery by the same chemist of two biphosphates of soda, agreeing in composition but differing in form; and lastly, the discovery of the pyrophosphates by my friend and townsman Mr. CLARK. Much, however, still remains to be done to complete the history of these interesting salts.

1. *Subarseniate and Subphosphate of Soda.*

The extraordinary disposition of arsenic and phosphoric acids to form subsesquisalts—such as the brown arseniate and the yellow phosphate of silver, the common subarseniates of lime, lead, &c.—is well known. Corresponding alkaline salts exist, which merit the consideration of chemists.

To a strong solution of arseniate or phosphate of soda add a solution of caustic soda till the liquor feels soapy between the fingers. At least half as much soda as already in the salt must be added, but an excess of alkali is not injurious. Concentrate the liquor till a pellicle forms on its surface, and then allow the solution to cool. At the temperature of 150°, tufts of slender prismatic crystals appear in it; these rapidly increase in quantity, and finally fill the vessel. The crystals must be drained as well as possible, and the mother-liquor may be thrown away, as it contains little else than the excess of caustic soda and the soluble impurities of the salts. It is necessary, without loss of

time, to redissolve the crystals in twice their weight of hot water, to filter the solution through paper, and to recrystallize.

Both salts crystallize readily, as their solutions cool, in the form of six-sided prisms, which are generally slender. The prism is often terminated by a flat surface, which appears to be a right section. The angles of the crystals were not measured, but two of them are much more obtuse than the remaining four. The subarseniate may be procured in crystals of larger size than the subphosphate, but of the same form. These salts in the crystalline form are not altered by exposure to the air, but in solution they absorb carbonic acid; and when again crystallized, a portion of carbonate is found to adhere pertinaciously to the crystals. It is easy, however, to produce fine crystals by the process described, free from carbonic acid, and apparently pure.

A solution of the subarseniate is precipitated exactly neutral, by an excess of fused nitrate of silver, the brown subarseniate of silver falling down, which proves the alkaline subarseniate to be in the same state of neutrality as the metallic subarseniate, and consequently of a similar constitution. The subphosphate gives, with the same reagent, the yellow subphosphate of silver, and leaves a liquid either neutral or very faintly alkaline by the most sensible cudbear paper. The alkalinity, however, must be accidental, as it disappears on the addition of the smallest quantity of acetic acid. These salts, therefore, rank as subsesquisalts, containing one proportion and a half of base to one of acid*. They are interesting as the only known soluble salts of that constitution. The subphosphate had been previously crystallized by Dr. Dalton and recommended as a reagent†; but it was supposed to contain twice as much soda as the common phosphate. Mitscherlich also infers the existence of a subsesquiphosphate of soda, from the quantity of carbonic acid expelled, when phosphate of soda is calcined with carbonate of soda‡. The same salt appears likewise to have fallen into the hands of Dr. Thomson, as an accidental product, but is described as a carbono-phosphate of soda, being probably impure§.

In regard to the properties of these salts. They are strongly alkaline to the taste, and act upon chlorine and iodine like free alkalies. Indeed the excess

* Three atoms oxygen in the base for five atoms oxygen in the acid.

† Manchester Memoirs, N.S. vol. iii. p. 12. ‡ Annales de Chimie et de Physique, tom. xix. p. 363.

§ First Principles, &c. vol. ii. p. 451.

of their alkali is separated by the weakest acids, even by carbonic acid, and the common rhomboidal phosphate or arseniate afterwards appears on crystallizing. When the pure crystals are thrown into neutral nitrate of ammonia, the volatile alkali is disengaged. At 60° Fahr. 100 parts water dissolve 28 crystallized subarseniate of soda; and the crystals by themselves melt at 186°.

At 60°, 100 parts water dissolve 19·6 crystallized subphosphate of soda, and the crystals melt at 170°. Hence, although more fusible, they are less soluble than the crystals of subarseniate.

It is a fact of extraordinary interest, that the acid of this subphosphate is not convertible into pyrophosphoric acid by the action of heat upon the salt, like the acid of the common phosphate of soda. Indeed, when the pyrophosphate of soda itself is calcined with an excess of carbonate of soda, carbonic acid is expelled, and the former salt passes entirely into subphosphate of soda, which crystallizes in the usual form, and contains not pyrophosphoric but phosphoric acid. This change takes place equally well although both the carbonate and pyrophosphate be made anhydrous before being calcined; and we can obtain consequently an anhydrous subphosphate of soda. A solution of pyrophosphate of soda, to which sufficient caustic soda or carbonate of soda has been added, cannot be evaporated to dryness without becoming subphosphate. But pyrophosphate of soda may be boiled with caustic soda for hours without sensible alteration, provided the solution is not evaporated to dryness; and it crystallizes afterwards in its original form, exhibiting no disposition whatever to form a subpyrophosphate.

I may premise thus early, that the preceding facts, and many others to be afterwards enumerated, appear to be most easily explained on the hypothesis that phosphoric acid, in contradistinction to pyrophosphoric, is characterized by a disposition to unite with three atoms of base;—that common phosphate of soda, for instance, is a phosphate of soda and of water, and that its symbol is $\dot{N}a^2\dot{H}\dddot{P}$. Now for this basic water an atom of any of the usual bases may be substituted; an atom of soda, for instance, as in our subphosphate, of which the symbol is $\dot{N}a^3\dddot{P}$; an atom of oxide of silver, as in the yellow subphosphate of silver; and so in the other subphosphates. We have here a clue also to the disposition of phosphoric acid to form such subsesquisalts; for the common phosphate of soda which we use as a precipitant

exchanges its basic water for a fixed base. Hence, although a phosphate of neutral composition, such as the common phosphate of soda, cannot be made anhydrous without becoming pyrophosphate, the subphosphates, having an excess of fixed base, may be anhydrous, as was observed by Stromeyer; and indeed they are not convertible into pyrosalts.

The pyrophosphoric acid of Clark, which exists in the pyrophosphate of soda, appears to unite with only two atoms of base.

Phosphoric acid, produced in white flakes on burning phosphorus in air or oxygen gas, or the acid heated to redness by itself, constitutes, we shall afterwards find, a third modification of phosphoric acid. This third variety is characterized by alone coagulating albumen; by producing precipitates, even when free, in muriate of barytes, lime, &c.

Much time and attention were devoted to the determination of the water of combination of the foregoing subsalts. Both salts, when dried by heat, act upon glass with as much violence as the caustic alkalies, absorb carbonic acid with avidity, and retain a small but notable quantity of water under the most intense heat. The problem is therefore environed by difficulties.

(1.) Excellent hard crystals of subarseniate of soda lost nothing when reduced to powder and exposed to a dry atmosphere. Dried most cautiously in a platinum flask, on a sand-bath,

			Water.	
In Exp. 1.	42·42 grs. crystallized salt lost	21·13	49·81	per cent.
—— 2.	26·04 ——	12·94	49·69	——
—— 3.	41· ——	20·40	49·76	——
		Mean ...	49·75	

These results exhibit the entire quantity of water which the salt abandons by the action of heat alone; for an adopter being applied to the flask and made tight by luting, the salt was in each case subsequently heated for a few minutes to full redness, without any further loss of weight. No sensible absorption of carbonic acid occurred when the experiment was conducted in this manner. The salt was not fused; indeed it is not fused by a strong white heat.

But the calcined salt still contains water, as may be shown by fusing it with any body capable of combining with the excess of alkali. A quantity of bichro-

mate of potash in a glass tube may easily be kept in a state of fusion by the flame of a lamp. On throwing the calcined subarseniate into that fused and anhydrous salt, a notable quantity of water was given off, which condensed in the upper part of the tube.

Exp. 1. About 50 grains of the fused bichromate of potash, as it falls to pieces in the progress of cooling, but still warm, were introduced into the platinum flask containing 13·1 grains of calcined salt of Experiment 2nd above, and the whole maintained in a state of fusion for a considerable time at a low red heat, by means of a spirit-lamp. The salt lost 0·16 grain additional, and no green oxide of chromium was formed. This is an additional loss of 0·62 per cent. on the crystallized salt, and makes the entire water amount to 50·31 per cent.

Exp. 2. 25·57 grains of crystallized subarseniate were introduced, with a little water, into a crucible containing already 20 grains of pure anhydrous arsenic acid, calcined immediately before by a spirit-lamp heat which does not decompose it. The whole was cautiously dried, and finally fused by a red heat. The loss amounted to 12·8 grains, or 50·06 per cent.

Exp. 3. To 25·11 grains of binarseniate of soda previously fused in a crucible, 45·5 grains of subarseniate of soda were added, with water sufficient to dissolve the whole. Cautiously evaporated to dryness in a crucible partially covered by a watch-glass, as usual, and finally heated to redness, the subarseniate lost 22·88 grains, or 50·29 per cent. This last is certainly the preferable mode of determining the problem.

The mean of the three experiments detailed gives the entire water in the subarseniate of soda 50·22 per cent., while the proportion expelled by heat alone amounts to 49·75 per cent. Hence the quantity retained amounts to 0·47 per cent.

When the calcined salt retaining this small quantity of water is reduced to an impalpable powder, and heated afresh on the sand-bath, the whole water is expelled, with the exception of a mere trace.

Although small, the quantity of water retained in the calcined salt could not be passed over without investigation, as it may afford indication of some internal change which the subarseniate undergoes. Calcined in the open fire, this salt absorbs carbonic acid gas, and afterwards effervesces briskly with an

acid. The salt becomes at the same time anhydrous. This may arise from the hydrate of soda becoming carbonate of soda.

A portion of subarseniate of soda, dried by the spirit-lamp, was reduced to powder, and calcined anew with a mass of carbonate of ammonia in the same crucible, so that the maximum absorption of carbonic acid (as it was imagined,) might take place. The salt was kept uncovered for some time, at a low red heat, after all the volatile carbonate had escaped. It was found that the quantity of carbonic acid absorbed, might be determined most exactly by disengaging the gas over mercury by means of a small quantity of muriatic acid slightly diluted.

Eleven grains of calcined salt afforded 0·49 cubic inch of carbonic acid gas, at 60°; of which the weight is 0·23 grain, and which is equivalent to 0·56 grain of carbonate of soda. Hence, by calculation, 100 parts of the calcined salt contain 2·1 carbonic acid, or 5·1 carbonate of soda; 2·1 carbonic acid are equivalent to 0·9 water; but 50 calcined salt, it was previously shown, retain 0·47 water, and therefore 100 calcined salt retain 0·94. It would thus appear that the carbonic acid is just in quantity sufficient to occupy the place of the water. The carbonic acid is not expelled by an intense white heat.

The supposition is quite inadmissible that our salt contains the notable quantity of soda which becomes carbonate, as a casual impurity, and not essential to its composition; for the salt employed in all these experiments was in large, clear and perfect crystals. Such a supposition is also opposed by the analytic determination of the soda.

The quantity of water in the salt, namely, 50·22 per cent., is not easily reconciled with our best data for atomic weights. Adopting the atomic weight of arsenic acid, given by Berzelius, which I had an opportunity of verifying, a salt of

*24 atomic proportions of water correspond with 50·82 per cent.
23½ ——— 50·29 ———
23 ——— 49·75 ———

Our experimental result agrees closely with the middle number, and is perhaps

* We are obliged to adopt the double atom of arsenic acid here ($\dot{A}s = 1440{\cdot}1$); and consider these subsalts as consisting of one proportion of arsenic acid (containing five proportions oxygen,) and three proportions of base (containing three of oxygen).

compatible with either 23 or 24 atoms of water. Chemists will probably agree with me that the last supposition is the most likely. If so, it is curious that the subarseniate differs only from the neutral arseniate, by the substitution of an atom of soda for an atom of water, for the last salt contains 25 atoms of water.

It is well known that the analytic determination of the acid in the arseniates and phosphates is attended with considerable difficulty, chiefly from unsteadiness in the proportions of the precipitates.

41·87 grains of crystallized subarseniate of soda, precipitated by an excess of pure acetate of lead, gave a neutral mother-liquor, and a quantity of subarseniate of lead, which successfully washed by decantation, without the use of a filter, and heated to redness, weighed 46·41 grains; 35·17 grains of this subarseniate of lead, freshly calcined, were dissolved entirely in water, acidulated with nitric acid; and, precipitated by sulphate of soda, gave 35·86 grains of sulphate of lead, which contain 26·38 oxide of lead. In such calculations the atomic numbers of Berzelius are adopted in this paper. Hence the portion of subarseniate of lead analysed contains 8·79 arsenic acid; and the whole 46·41 grains subarseniate of lead contain 11·62 arsenic acid, which is therefore the quantity of arsenic acid in the portion of subarseniate of soda submitted to analysis. Hence crystallized subarseniate of soda contains 27·76 per cent. arsenic acid.

The soda of the salt was determined in the usual way. The arsenic acid being precipitated by acetate of lead, and received on a filter, the excess of lead was removed by carbonate of ammonia added to the hot liquor. The solution of acetate of soda resulting, was then filtered, concentrated, and transferred into a platinum crucible, in which it was evaporated on the sand-bath to dryness with the greatest caution; partially covered by a watch-glass; and eventually decomposed by a full red heat gradually applied to the crucible still covered by the watch-glass, as from the effervesence during the decomposition of the acetates, small particles are thrown up with considerable force, and would otherwise be lost. The solution of carbonate was then filtered, evaporated to dryness in a crucible, and raised to a strong red heat. The following results were obtained after a knowledge of all the necessary precautions had been acquired.

Exp. 1. 39·98 grains of crystallized subarseniate of soda yielded 15·61 carbonate of soda, equivalent to 9·14 soda; or the salt contains 22·87 per cent.

soda. Now 22·87 soda contain 5·85 oxygen, and 50·22 water contain 45·74 oxygen; or the oxygen in the water is 7·819 times that in the base. But as there are three atoms of oxygen in the base, there are 7·819 × 3, or 23·457 atomic proportions of oxygen in the water.

Exp. 2. 40·3 grains of crystallized subarseniate of soda yielded 15·73 carbonate of soda, equivalent to 9·21 soda; or the salt contains 22·85 per cent. soda.

Exp. 3. 21·62 grains of crystallized salt gave 8·41 carbonate of soda, equivalent to 4·93 soda; or 100 grains of crystallized salt contain 22·8 soda.

These experiments agree very closely among themselves; but I am doubtful whether this method gives the alkali with perfect precision in the case of the arseniates, but somewhat in excess. The general result of the analyses may be stated as follows:

Subarseniate of soda.

	Experiment.	Theory of 23 atoms water.
Arsenic acid	27·76	27·69
Soda	22·85	22·55
Water	50·22	49·75
	100·83	100·

(2.) The crystals of subphosphate of soda submitted to analysis were smaller than the crystals of subarseniate, but well formed and remarkably pure, containing not a trace of sulphuric, muriatic, or carbonic acid.

Exp. 1. A quantity of the salt had been reduced to powder and exposed to a dry atmosphere, in which it lost a little weight; of the salt so dried, 29·12 grains lost by red heat in a platinum retort, as described in the case of the subarseniate, 16·07 grains; which is 55·19 per cent. water.

Exp. 2. 21·83 grains of crystallized salt heated in the platinum retort on the sand-bath lost 12·05 grains, or 55·2 per cent. Being heated thereafter to redness by the lamp, the loss appeared to be only 12·01 grains; but the calcined salt had acquired a little carbonic acid, notwithstanding the precautions, and now effervesced with acids. These two experiments give, therefore, the same result.

The salt still retained a little water, about twice as much as the subarseniate in the same circumstances. But when the calcined subphosphate was

reduced to an impalpable powder, and heated anew, the greater portion of the water which had been retained was readily expelled.

Exp. 3. Fused with recently ignited protoxide of lead, 19·36 grains of crystallized salt lost 10·84 grains, or 55·99 per cent., which is the entire water in the salt.

Exp. 4. To 17 grains of biphosphate of soda recently fused in a crucible, 35·54 grains of crystallized subphosphate of soda were added, with a quantity of water, in which the salts were dissolved together by digestion. Evaporated to dryness, and calcined by a red heat without fusing, the salts sustained a loss of 19·92 grains. Hence 100 crystallized salt have abandoned 56·05 water.

Calcined with access of carbonic acid, the subphosphate, like the subarseniate, absorbs that gas, becoming at the same time anhydrous; but redissolved in water and evaporated, it affords crystals of the original form and composition, which retain a trace of carbonic acid.

A quantity of the subphosphate ignited in an open crucible was found to consist of

Subphosphate of soda	100
Carbonic acid	2·3

Another portion, calcined with a mass of dry carbonate of ammonia in the same crucible, consisted of

Subphosphate of soda	100
Carbonic acid	2·25

A quantity of subphosphate of soda dissolved in a solution of carbonate of ammonia, was thereby purposely contaminated by a large quantity of carbonic acid, and calcined three times in succession with alternate pulverization. It finally consisted of

Subphosphate of soda	100
Carbonic acid	1·7

Or of

Subphosphate of soda	100
Carbonate of soda	4·3

It seemed to follow from the last experiment, that, by pulverizing the salt

and recalcining it, the quantity of carbonic acid may be diminished, as in the case of water in the hydrate of the same salt.

The calcined salt did not fuse at a strong white heat, but acquired a beautiful blue tint where in contact with platinum.

By the mean of two experiments detailed above, 100 crystallized subphosphate of soda contain 56·03 water. Twenty-three atoms would be 55·61 per cent. only, and twenty-four atoms water would be 56·66 per cent.*

The soda of the subphosphate was determined directly, in the same manner as the soda of the subarseniate.

Exp. 1. 41·23 grains of crystallized salt gave 17·27 carbonate of soda, equivalent to 10·12 soda. Hence 100 of crystallized salt contain 24·54 soda.

Exp. 2. 40 grains of the crystallized salt gave 16·97 carbonate of soda, equivalent to 7·03 soda, or 24·87 per cent. soda.

It was also attempted to determine the phosphoric acid directly, by precipitating with nitrate of silver, which leaves a mother-liquor either exactly neutral or feebly alkaline. The result was 18·6 per cent. phosphoric acid, which certainly approaches the truth. But the subphosphate of silver was discovered to carry down with it a portion of nitrate of silver, which comes away gradually, but which no continuance of washing is sufficient entirely to remove. The subarseniate of silver has the same property. Thus to precipitate 27·5 grains of crystallized subphosphate of soda, 38·1 grains of fused nitrate of silver were found necessary, which is more than one grain above the theoretical quantity: 25 grains of crystallized subarseniate of soda required 31·08 grains of nitrate of silver for complete precipitation, which is an equally excessive proportion of the precipitant. From these precipitates fumes of nitrous acid were evolved, on the application of heat. When nitrate of ammonia, exactly neutral, was first mixed with the solution of subarseniate of soda, a less quantity of nitrate of silver sufficed; 30·05 grains of nitrate of silver left still an excess of arsenic acid, when added to 25 grains of subarseniate of soda; but on introducing 0·06 grain of nitrate of silver additional, the liquid contained an excess of silver: but the nitrate of ammonia retains in solution a trace of subarseniate of silver. It is curious that the pure subarseniate of silver, precipitated in the way last mentioned, withdraws nothing from a solu-

* Assuming the double atom of phosphoric acid $(\dot{\dot{P}}) = 892{\cdot}3$.

tion of nitrate of silver. This shows that the subarseniate of silver carries down the soluble nitrate only at the moment of precipitation, and by the agency of some chemical affinity very different from the attraction of animal charcoal for many bodies in solution.

The addition of a little acetic acid to a solution of subarseniate of soda, occasioned a notable deficiency in the amount of the precipitate by nitrate of silver.

It may be safely concluded from the quantity of soda which it contains, that the salt under examination is a subsesquiphosphate. The crystals consist of

Subsesquiphosphate of soda	43·97
Water	56·03
	100·

2. *Subphosphates and Subarseniate of Potash.*

The corresponding salts of potash were formed, but I did not succeed in obtaining them in a state of purity.

When caustic potash is added in excess to phosphoric acid, the solution becomes muddy although dilute, and a precipitate partly flaky and partly in a gritty powder shows itself. This precipitate in both conditions is a diphosphate of potash according to Dr. Thomson, who examined it*. When arsenic acid was treated in the same way, with excess of caustic potash, no insoluble salt fell; but on concentrating the solution it crystallized almost entirely in the form of minute needles. These crystals I could not free from carbonate; and either of themselves, or rather from the presence of free potash, they were deliquescent in the extreme. There is every reason to believe that they constitute a subsalt corresponding with the subsalt of soda.

A crystallized subphosphate of potash, however, may be formed by fusing together phosphoric acid and an excess of carbonate of potash (bicarbonate was employed). A strong solution crystallizes in small needles, like the preceding subsalts. These crystals were exceedingly soluble, and retained a little carbonate of potash, but were not at all deliquescent. They precipitated the yellow subphosphate from nitrate of silver in excess, and left a neutral or slightly alkaline mother-liquor.

* Inorganic Chemistry, vol. ii.

The soluble subarseniate and subphosphate of soda present a favourable opportunity of forming the corresponding insoluble earthy and metallic subsalts. Salts of this formula, it is well known, generally present themselves, even when the alkaline salts of arsenic and phosphoric acid, which are neutral in composition, are employed as precipitants. But the consequent and unavoidable acidity of the mother-liquor is apt to prevent complete precipitation, the phosphates, with few exceptions, being soluble in an excess of acid.

3. *Subarseniate and Subphosphate of Barytes.*

To a solution of subarseniate of soda, chloride of barium was gradually added till in slight excess. The precipitate first appeared gelatinous, consisting of little pellucid masses; but on the application of heat to the liquor, the precipitate immediately became small-flaky and heavy, and subsided. The mother-liquor proved strongly alkaline, and the precipitate, it was found, had taken down with it a quantity of subarseniate of soda, of which protracted washing did not entirely divest it. Berzelius has remarked that barytes is most disposed to combine with phosphoric acid in the proportion of a neutral salt, which is true also of arsenic acid, and accounts for the above derangement of precipitation, a little of the neutral salt being probably formed. The process was reversed, and into a large quantity of neutral solution of chloride of barium, a solution of 50 grains of subarseniate of soda was gradually poured with stirring. A pulverulent heavy precipitate fell easily. The filtered mother-liquor did not fully restore the blue colour of reddened litmus paper in some hours, but acted at once as an alkali on cudbear paper, although in a feeble manner. The precipitate, however, was easily washed. While still wet on the filter, it had acquired a sensible trace of carbonic acid; and when heated, it displayed, like the corresponding alkaline salts, considerable avidity for carbonic acid. 22·33 grains of this salt, heated to redness by the spirit-lamp, were found by one analysis to be composed of

Carbonic acid	0·18	
Arsenic acid	7·10	32·06
Barytes	15·05	67·94
	22·33	100

If we may trust a single analysis, the salt contains an excess of barytes; for by theory a subsesquiarseniate of barytes should be composed of

Arsenic acid	1440·1 . . .	33·4
Barytes	2870·6 . . .	66·6
	4310·7	100

When a solution of subphosphate of soda is added to chloride of barium, a corresponding subphosphate of barytes subsides as a heavy, small-flaky precipitate, leaving a mother-liquor neutral or nearly so.

4. *Subarseniate and Subphosphate of Lime.*

The subarseniate of lime, formed by pouring chloride of calcium into subarseniate of soda, is a bulky gelatinous body, and continues so although heated. It carries down subphosphate of soda, but to a less extent than the subarseniate of barytes prepared in the same way. Prepared by the converse process, the subarseniate precipitates in little gelatinous masses, as before; although the general aspect is flaky, particularly after the liquor has been heated. The mother-liquor from 50 grains of subarseniate of soda precipitated in this way, required several minutes to affect reddened litmus paper unequivocally, being slightly alkaline. The precipitate appears, therefore, to correspond closely with the subarseniate of soda. The properties of the subphosphate appeared to be similar. Such a phosphate occurs native, but hitherto had not been formed artificially.

Berzelius proves the existence of another subphosphate of lime, which has acquired the name of the Subphosphate of lime of bones,—a gelatinous body, formed when muriate of lime is poured into an excess of phosphate of soda; or when phosphate of lime, dissolved in muriatic acid, is precipitated by ammonia. The composition of this phosphate is singular and without parallel, consisting, on the simplest view which can be taken of it, of three proportions of phosphoric acid and four of lime. It is designated by Gay-Lussac the $\frac{3}{4}$ phosphate, while the preceding compound is called the $\frac{2}{3}$ phosphate. The anomaly may in some measure be removed by viewing this salt as a compound of one proportion of the neutral phosphate of lime and two proportions of the subsesquiphosphate. Its formula would be as follows:

$$\dot{C}a^2\ddot{\dot{P}} + 2(\dot{C}a^3\ddot{\dot{P}})$$

Berzelius finds the calcined bones of the ox to be composed of such a phosphate of lime with a small quantity of carbonate of lime. His analysis may be stated thus:

Phosphate of lime	Phosphoric acid . .	46·45	
	Lime	49·7	51·86
Carbonate of lime	Lime	2·16	
	Carbonic acid . .	1·69	
		100	

The only doubt we can entertain of this view arises from the circumstance, that the presence of carbonic acid in the calcined phosphate of the bones is no proof of the existence of carbonic acid in the same body previous to calcination. We know that the subphosphate of soda absorbs a variable quantity of carbonic acid when calcined. The quantity of carbonic acid which the earth of bones contains is variable. A specimen which had been calcined more than a year before, contained 1·2 per cent. As this was below the determination of Berzelius, I reduced a portion to fine powder, and kept it for some minutes in an atmosphere of carbonate of ammonia, at a heat scarcely amounting to redness. The earth, however, by this treatment, had lost carbonic acid, and now contained only 0·5 per cent. Another portion reduced to powder, and gently heated in the same way, but without the carbonate, retained 0·57 per cent. carbonic acid.

The earth of bones, although calcined at a high temperature, contains phosphoric acid and not pyrophosphoric acid, the excess of base preventing the transition. But eight ounces of earth of bones being mixed with two ounces of sulphuric acid, and calcined again, were found thereafter to contain a large proportion of an acid which precipitated silver white.

5. *Subarseniate and Subphosphate of Lead.*

When the subarseniate or subphosphate is poured into a solution of acetate of lead in excess, the salt which falls was found to contain an excess of base. I therefore had recourse to the converse process. To 50 grains of subarseniate of soda in solution, 50 grains of acetate of lead in solution were gradually added with stirring, which left an excess of the first in solution. The subarseniate of lead was washed by decantation, till the water digested upon it ceased to ac-

quire an alkaline reaction. Heated to low redness, this substance acquired a yellow tint, but became white again on cooling; it was found somewhat aggregated together by the heat, but not fused. 15·25 grains were dissolved in dilute nitric acid, and precipitated by sulphate of soda added in excess. The sulphate of lead amounted to 15·41 grains, equivalent to 11·336 oxide of lead. The washings became of a brown tint on the addition of sulphuretted hydrogen, but the quantity of lead which they contained was too small to be appreciated. This analysis affords a striking confirmation of the atomic weight of arsenic acid, deduced by Berzelius from his analysis of arsenious acid by sulphur. I place together the results of my analysis, and the composition of the same salt calculated by that accomplished analyst from his own data.

	Analysis.	Theory of Berzelius.
Arsenic acid	25·67	25·61
Oxide of lead	74·33	74·39

In another analysis, the quantity of lead which escaped precipitation by the sulphate of soda was even more notable, from the presence of too much nitric acid. The result was 74·18 per cent. oxide of lead. This salt I believe to be most suitable of all the arseniates for determining directly the combining proportion of arsenic acid.

II. *Of the neutral Phosphates and Pyrophosphates.*

It is well known that the phosphate of soda is a highly alkaline salt, although generally viewed as neutral in composition. Mitscherlich found that a solution of this salt required the addition of half as much acid as it already possesses, to deprive it of an alkaline reaction. This result I had an opportunity of confirming in a general way, although I could not ascertain the exact point of saturation, from the test-paper proving doubtful in its indications for a considerable distance on either side of the supposed point of neutrality.

Although Mr. Clark's experiments afford strong evidence that the phosphate of soda of the usual form contains twenty-five atoms water, yet it was thought proper to settle the point by a careful experiment. Pure crystals were employed, which had been formed about six months before and were dry, but

possessed bright surfaces. A portion for analysis was reduced to powder in a damp day, and pressed for twenty hours between folds of dry blotting paper. A crystal exposed to the air at the same time, beside the paper, remained perfectly bright. Carefully dried and heated to redness, 35·44 grains of the salt lost 22·29 grains of water. Hence the crystallized salt consists of

Phosphate of soda	37·1
Water	62·9
	100

Our result gives 25·22 atoms water, and therefore confirms the previous determination.

Mr. Clark has the entire merit of discovering the change which takes place upon phosphate of soda by the action of heat, and his original description of the pyrophosphate of soda is very complete*. He likewise remarked the connexion between the transition into pyrophosphate and the loss of the last atom of water of the phosphate of soda, which atom requires a much higher temperature to expel it than the other twenty-four; but he did not entertain the idea, broached in this paper, of the basic function of that atom of water in the constitution of the salt.

The phosphate of soda contains three atoms base; namely, two atoms soda and one atom water; and when added to the earthy or metallic salts, gives precipitates which uniformly contain three atoms base, namely, three atoms of the foreign oxide, as in the case of the subphosphate of silver, or one atom water and two atoms of the other oxide, as in the phosphate of barytes. These precipitations afford the strongest proof of the basic function of that atom of water which is essential to the phosphate of soda, as they can be accounted for, on the usual laws of double decomposition, on no other supposition. The pyrophosphate of soda, on the other hand, contains only two atoms soda as base, and gives, accordingly, bibasic precipitates.

In his Traité de Chimie, Dumas speaks in an incidental manner of a third phosphate of soda, differing from the two preceding, obtained by keeping for a long time a solution of the common phosphate at the boiling temperature; but I have been able to discover no description nor any other notice of this new

* Edinburgh Journal of Science, vol. vii. p. 298.

salt. To investigate the point, I boiled for several hours each day during three weeks, an ounce of phosphate and the same quantity of pyrophosphate of soda, in separate flasks, with several ounces of water. A considerable, heavy, flaky precipitate soon appeared in both, but was most abundant in the pyrophosphate. The flasks, on removing the liquors from them, were found strongly corroded. The solution of pyrophosphate, on being filtered and concentrated, yielded crystals of our subphosphate of soda to the last drop. It had evidently derived alkali from the glass, while a portion of its acid had also united with the oxide of lead of the glass, and formed a precipitate insoluble both in water and in acids. But the solution of the boiled phosphate of soda filtered, concentrated, and set aside in a cool place, became gradually filled with crystalline plates, which were the finest films and had a beautiful silky lustre. The mother-liquor being poured off, yielded a second, third, and fourth crop of crystals of the same singular appearance. The last drops of the liquor were still alkaline, but I thought not so strongly so as the phosphate of soda. The crystallization in these cases was gradual, and not hurried and confused. To look at these silky films, nobody would have guessed them to be phosphate of soda. But on examining them minutely, complete rhomboidal plates of the common form of phosphate of soda were distinguished; and the water of crystallization of the salt was found to be exactly the same as that of the rhomboidal phosphate. In a dry atmosphere, too, a portion of the silky plates, and an equal quantity of pounded crystals of the common phosphate lost their water pari passu. It is evident, therefore, that we have nearly obtained the phosphate of soda of an unusual appearance. I shall have occasion, in the sequel of the paper, to notice other circumstances in which the phosphate presents itself of this appearance. On dissolving and recrystallizing the silky plates, the usual solid rhomboids presented themselves. It was also determined by experiment, that neither the phosphate nor pyrophosphate of soda is altered by being boiled for a week in water contained in a silver capsule, in which no decomposition can take place. There can be no doubt, therefore, that these salts undergo no change at the boiling temperature, unless they react upon the material of the containing vessel. Even at the usual temperature a solution of these alkaline salts corrodes a glass phial and becomes turbid in the course of months.

III. *Of the Superphosphates.*

1. *Of the Biphosphate of Soda.*

This salt admits, as I shall immediately show, of so many changes in its constitution and properties, as to entitle it to be considered one of the most interesting of chemical substances. The facts which I have to communicate on this subject are certainly the most extraordinary of the paper, and were determined with care and considerable difficulty.

I had an opportunity of noticing the dimorphism of this salt, and confirmed the observation of MITSCHERLICH, that both forms of crystals possess the same chemical properties and the same proportion of water. Of the four atoms of water which the crystals contain, they lose, I find, two atoms at the temperature of 212°, and not a particle more till heated up to about 375°.

1st. Thus 4·96 grains of the crystals reduced to powder, when dried on the water-bath for several days, retained only 0·76 water, or consisted of

Biphosphate of soda	100
Water	18·09
	118·09

This is as nearly as possible one half of the entire water in the crystals, which by the mean of MITSCHERLICH's experiments consist of

Biphosphate of soda	100
Water	35·57
	135·57

2nd. 10·01 grains of the salt dried on the water-bath retained 1·53 water, which is 18·04 water to 100 dry salt, or the same result as in 1°.

3rd. 50 grains of the crystals lost 6·52 grains on the water-bath; their entire water being by theory 12·77.

There is every reason to believe that the two atoms of water retained are essential to the constitution of the biphosphate of soda, and that its composition is expressed by the following formula,

$$\dot{N}a\dot{H}^{2}\ddot{\ddot{P}}$$

It contains three atoms base, namely, one atom soda and two atoms water, united to a double atom of phosphoric acid. The salt cannot sustain the loss of any portion of this water without assuming a new train of properties. There are accordingly three atoms oxygen in the base, (two in the water, and one in the base,) and five in the acid. When crystallized the salt contains, besides, two atoms water of crystallization.

The crystals of biphosphate of potash contain only the two essential atoms of water, and the lustre of their surfaces is not affected by a water-bath heat, nor by any degree of heat under 400° Fahr.

A solution of either of these alkaline biphosphates, when added to nitrate of silver, occasions a copious precipitation of the yellow subphosphate of silver; and if ammonia be cautiously added, so as merely to make up the excess of nitric acid disengaged, the whole phosphoric acid falls in that state. It is to be here remarked, that the three atoms base of the alkaline biphosphate are replaced in this precipitation by three atoms of oxide of silver.

2. *Second variety of Biphosphate of Soda, or Bipyrophosphate of Soda.*

When a quantity of the biphosphate of soda, previously dried on the water-bath, is afterwards gradually heated on a solder-bath, it begins to lose water at about 375°, and before it is raised to 400° it has lost exactly half the water which it possessed, or one atom. The dried salt may thereafter be heated up to 450°, and maintained for an hour or more at that temperature, without sustaining any further loss. When rapidly heated in a glass tube, the salt undergoes semifusion at some point near 400°, and the same quantity of water comes off in a state of ebullition.

1st. Thus 2·62 grains of the salt dried on the water-bath, when heated in a thin glass tube, lost at once 0·2 grain water on attaining 400°, which is one half of the water which it possessed, namely, 0·396 grain; while it was exposed again for four hours to a temperature between 450° and 470°, without losing 0·01 grain additional.

2nd. In one experiment, 18·45 grains of the crystallized biphosphate lost 3·68 grains by 400° Fahr. on the solder-bath. This is 27·04 of the 35·57 parts water, which are united to 100 dry salt in the crystals. The salt has lost 3·04 atoms of water.

3rd. A quantity of the salt, previously deprived of its two atoms water of crystallization, was kept for three hours at a temperature ranging between 400° and 460°. 11·19 grains of the salt so dried contained 0·9 water, or consisted of

Biphosphate of soda	100
Water	8·72
	108·72

The water retained amounts to 0·981 atom, which is a close approximation to 1 atom.

4th. A quantity of the salt which had been heated to 400° was dissolved in water, evaporated to dryness, and exposed again for some days on a solder-bath at a temperature not exceeding 400°. 13·94 grains of the salt so dried still retained 1·06 grain water, as was found by fusing the salt at a red heat; or it consisted of

Biphosphate of soda	100
Water	8·23
	108·23

This is less than one atomic proportion, which is 8·89 parts; but the temperature at which the salt loses its entire water is elevated no great number of degrees above that in which it loses the atom under consideration; and a protracted exposure to the air at 400° occasions the partial dissipation of the last atomic proportion of water, as in this experiment.

The heated salt which retains one atom water, is still very soluble and possesses an acid reaction, but it is altered essentially in properties. Added to nitrate of silver, it produces a sparing chalky white, pulverulent precipitate, and a very acid liquor. By the cautious addition of ammonia so as merely to take up the excess of nitric acid, the entire phosphoric acid is precipitated in the same state. The precipitate proved, on analysis, to be the pyrophosphate of silver, containing two atoms oxide of silver to one double atom phosphoric acid.

Of this precipitate, heated to redness but not fused, 18·75 grains dissolved in nitric acid and precipitated by muriatic acid, afforded 17·82 grains chloride of silver, equivalent to 14·41 oxide of silver. The composition of this phosphate

and of the pyrophosphate of silver, with which it appears to correspond, is as follows:

	Experiment.	Theory.
Oxide of silver	76·85	76·49
Phosphoric acid	23·15	23·51
	100	100

Added to acetate of lead, this altered biphosphate likewise threw down the pyrophosphate of lead. The acid of this last salt was separated by sulphuretted hydrogen, and when afterwards neutralized by carbonate of soda, it afforded crystals of pyrophosphate of soda.

Now this variety of the biphosphate of soda, which may be called the bipyrophosphate, contains one atom of basic water, and its formula is,

$$\dot{N}a\dot{H}\ddot{\ddot{P}};$$

or it contains two atoms base like the salt of silver which it precipitates. This salt when treated with caustic soda affords the neutral pyrophosphate. It also occasions a precipitate in muriate of barytes, in which respect it differs from the proper biphosphate. I failed in all my attempts to obtain the bipyrophosphate of soda in a crystalline form. It uniformly dried up into the state of a friable white crust.

3. *Third variety of the Biphosphate of Soda.*

When the salt last described was exposed on the solder-bath for several days at a temperature between 400° and 470°, it lost weight; only 3·48 parts out of the entire 35·57 water were retained in one experiment, and 2·81 parts water in another. The whole water was expelled, with the exception of 0·38 to 100 dry salt, in other experiments in which the salt was heated on the sand-bath, probably at a temperature not much under 600°. The salt became in fact very nearly anhydrous. Now on pouring water upon the salt so dried, the greater part of it dissolved at once, but an inconstant quantity remained undissolved, varying from 6·57 to 18 parts in 100 salt, but increasing with the intensity of the heat to which the salt had been exposed. This insoluble matter is a fourth variety of the biphosphate, which shall immediately be noticed. As this insoluble salt may be proved to be of the same composition as the biphosphate, it follows that the soluble portion is unaltered in composition.

The insoluble portion appears a heavy dense powder; yet as a part of it remains in suspension in the liquid for a long time, it is necessary to filter to obtain the soluble salt in a state of purity.

The preceding two varieties of biphosphate of soda have a distinct acid reaction, but the solution of this salt is exactly neutral, as was determined by very careful experiments. This property is the best distinctive character of this variety that I can mention. When a solution of the salt is concentrated, it does not deposit any of the insoluble variety, but allows rings of dry salt to form round the margin of the fluid, which are soluble. I have not succeeded in crystallizing it in the vacuum of an air-pump, or by other means which were employed. The salt always dried up into a friable white crust, which on one occasion, when dried at 212°, contained 11·56 parts water to 100 anhydrous salt. This salt occasions a precipitate in muriate of barytes like the preceding. With nitrate of silver it gives a considerable white pulverulent precipitate, and the liquid becomes strongly acid. 8·38 grains of this precipitate dried and heated to redness without fusing, were found to consist of 6·58 oxide of silver and 1·8 phosphoric acid, or 77·32 oxide of silver and 22·68 phosphoric acid = 100; while the neutral pyrophosphate of silver, containing two atoms oxide of silver, consists of 76·49 oxide of silver, and 23·51 phosphoric acid. The correspondence is sufficiently close to prove that our silver precipitate is the same neutral phosphate which presents itself when the second variety of biphosphate of soda is precipitated in the same manner. Like that variety, also, this form of the biphosphate afforded crystals of the pyrophosphate of soda when treated with caustic soda.

In regard to the exact constitution of this variety I entertain considerable doubt. We are warranted to presume that the biphosphate of soda can exist in an anhydrous condition soluble in water, and neutral in its reaction on litmus. The formula of the salt may be,

$$\dot{N}a\dddot{P}$$

It must, however, be allowed that no confirmation of this view of the constitution of the salt can be drawn from the composition of the silver precipitate. But the precipitate that should fall by theory, is the biphosphate of silver. Now no such salt exists, the biphosphate of silver described by Berzelius containing the new modification of phosphoric acid.

4. *Fourth or insoluble variety of Biphosphate of Soda.*

When any of the preceding varieties of the biphosphate of soda is heated for a few minutes at a temperature approaching but not amounting to low redness, it becomes anhydrous, if not so before, and the whole of it becomes insoluble in water. We are apt to overheat the salt in a crucible if a lamp be employed. I found it the most convenient process to introduce a quantity of the crystallized biphosphate into a platinum crucible, to place this in sand contained in a Hessian crucible, and to place the whole in a situation in an open fire where it would not be heated with rapidity. The time was watched when the sand was red hot to within a small space of the platinum crucible, and the whole then withdrawn from the fire. The appearance of the heated salt depends entirely upon circumstances. If the heat be applied rapidly, the salt undergoes fusion on losing its two essential atoms of water, and is found of a slaggy appearance and hard. But if the heat be applied in a gradual manner, the water escapes without any fusion, the powder merely shrinks and aggregates slightly together. In both states the resulting salt is the same. It may be reduced with ease to the most impalpable powder, and in this condition is very slowly acted upon by continued digestion in a large quantity of boiling water. When it does dissolve, it appears to pass into the preceding variety. But it may be inferred analogically, that if a more intense heat could be applied to the salt under consideration without inducing another change (to be described), the salt would be rendered perfectly insoluble. The biphosphate of potash affords this analogy.

This last salt contains only the two essential atoms of water. When heated above 400°, it begins to undergo a semifusion, although the heat has been applied in a gradual manner; and becomes partially insoluble, without exhibiting the changes which precede this in the biphosphate of soda. A still higher temperature, approaching a red heat, renders the biphosphate of potash as insoluble as the biphosphate of soda. But the biphosphate of potash may be fused in a platinum crucible and heated to whiteness without undergoing any further change of state; and after being thus strongly heated, it may be reduced to powder and digested in boiling water for hours without dissolving to such an extent as to afford a solution capable of affecting nitrate of silver in a sensible manner. It may be inferred, therefore, that if the biphosphate of soda could

be sufficiently heated, water would be wholly incapable of acting upon it. Dilute acids have no action upon this insoluble variety of biphosphate of soda; but alkalies by long digestion withdraw a portion of the phosphoric acid. So far as we can judge, the acid appears not to be in a modified or altered condition.

5. *Fifth variety of Biphosphate of Soda, or Metaphosphate of Soda.*

When the preceding insoluble variety, or the biphosphate in any condition, is heated in a platinum crucible to low redness, it undergoes fusion, and on cooling presents itself as a transparent glass, which deliquesces in a damp atmosphere and is highly soluble in water. But the fused salt has undergone a most extraordinary and permanent change of properties. The solution has a very feeble acid reaction when compared with crystallized biphosphate. Indeed the addition of 4·3 anhydrous carbonate of soda to one hundred fused biphosphate of soda imparted to the latter a distinct alkaline reaction. When this salt is added to nitrate of silver, the phosphoric acid is nearly entirely thrown down in gelatinous flakes, which aggregate together as a soft solid when heated near 212°, and correspond in composition with the soda salt. This silver precipitate loses acid when washed. It agrees in properties with the biphosphate of silver described by Berzelius, which, when washed, appeared to pass into a sesquiphosphate. He formed it by adding phosphoric acid to nitrate of silver, but the phosphoric acid employed by him must have been the glacial acid recently dissolved*.

When the fused biphosphate of soda is added to muriate of barytes, nearly the whole of the phosphoric acid precipitates with the barytes as a flaky gelatinous precipitate, which contains only one atom barytes to the double atom phosphoric acid, like the soda salt. But all the new properties of this salt depend upon the acid having undergone an essential change in constitution. The acid may be separated in the usual way, namely, precipitating by acetate of lead, washing the phosphate of lead and decomposing it by a stream of sulphuretted hydrogen gas. After exposure for some hours to allow the escape of the sulphuretted hydrogen, the acid liquid, without being neutralized, uniformly produced an opal-white flaky precipitate in muriate of barytes, which appeared

* Annales de Chimie et de Physique, tom. xlvi. p. 143.

immediately, unless the liquors were very dilute. This is also a character, I find, of phosphoric acid recently ignited per se. The acid of our salt possesses also the property of coagulating albumen. In fact, this acid appears to be the glacial phosphoric acid, which had been hastily assumed by recent writers upon this subject to be the pyrophosphoric acid, but is totally different. I shall take the liberty to designate provisionally the acid of the fused biphosphate of soda, the Metaphosphoric acid, from an hypothesis of its constitution to be immediately explained; and the fused salt itself, the Metaphosphate of soda.

The metaphosphate of soda is insoluble in alcohol. Its solution in water is not altered by time; at least no change could be perceived in a solution which had been kept for several months. When exposed to a temperature not exceeding 100° Fahr., the solution becomes viscid as it concentrates, and finally dries into a transparent brittle pellicle like gum. All my attempts to crystallize this salt by slow evaporation in the atmosphere, or by means of the air-pump, have failed. It never presented the slightest trace of crystallization. But many of the insoluble metaphosphates fall down in the state of hydrates, which have the fluid form; which may also be the form that the soda salt is disposed to assume.

The hydrated metaphosphate of soda dried over sulphuric acid in the vacuum of an air-pump, at the ordinary temperature of the atmosphere, was found to consist of

Metaphosphate of soda	100
Water	10·86,

by an experiment in which 11·64 grains of the hydrated salt lost 1·14 by fusion at a red heat. This is 1·22 atomic proportion of water.

When heated to 400°, the hydrated salt appears to retain 1 atom of water, and to pass into the bipyrophosphate of soda. 13·94 grains dried on the solder-bath at 400° for several days, retained 1·06 water; or the salt consisted of

Biphosphate of soda	100
Water	8·23
	108·23

This is less than one proportion of water (8·89); but the additional loss of water

which the salt sustained is accounted for by the length of time that it was exposed to the heat, which had the effect of converting a small portion of it into the insoluble and anhydrous variety. The dried salt when dissolved in water gave with nitrate of silver a chalky, white, heavy precipitate, which evidently was not the usual metaphosphate of silver. A portion of the salt was therefore precipitated by acetate of lead, and the acid liberated in the usual manner. The acid did not disturb albumen, nor precipitate muriate of barytes; but when neutralized with caustic soda it gave excellent crystals of the pyrophosphate of soda. There can be no doubt, therefore, that the metaphosphoric acid has returned to the condition of pyrophosphoric acid. The question arises, Is this transition the consequence of merely exposing the metaphosphate of soda to a particular temperature (400°), or does the water interfere and the transition arise from the affinity of phosphoric acid for water, as a base, with soda? Now, upon trial, the anhydrous fused metaphosphate of soda, as it is first formed, was found to undergo no alteration when kept for several days between 400° and 600°. The change is therefore peculiar to the hydrated salt, and effected by the interference of the water.

A solution of the metaphosphate of soda may be treated with caustic soda, and even boiled with it, without any change in the nature of the acid; at least, the saline solution still precipitates silver white, and the acid when separated coagulates albumen. The solution may even be evaporated gently to dryness, without a change of acid; but if dried by a sharp sand-bath heat, and if the alkali be present in sufficient quantity, the common subphosphate of soda is formed.

The metaphosphate of soda forms a series of insoluble metaphosphates when added to solutions of the earthy and metallic salts.

Metaphosphate of Barytes.

The metaphosphate of barytes has already been alluded to. As this salt is soluble in an excess of the metaphosphate of soda, it is best prepared by adding that salt to muriate of barytes in excess. There is an abundant, white, flaky precipitate, and the mother-liquor remains acid. This precipitate washed and dried at 600° Fahr. formed brittle masses; these masses heated to redness give off water and undergo an imperfect fusion. 11·86 grains of the ignited salt

were dissolved with considerable difficulty by pure nitric acid, and then precipitated by sulphate of soda. The sulphate of barytes amounted to 9·69 grains, which is equivalent to 6·36 grains barytes. The composition of this metaphosphate, and of a biphosphate of barytes, is as follows:

	Metaphosphate of Barytes.	Biphosphate of Barytes.
Barytes	53·62	51·75
Phosphoric acid	46·38	48·25
	100·	100·

Our salt is therefore 1·87 per cent. deficient in phosphoric acid. I thought that muriate of barytes had perhaps been carried down by the precipitate, but on examining a portion I found it free of muriatic acid.

But another quantity of the metaphosphate of barytes was prepared, with the precaution of having a more decided excess of muriate of barytes, and the liquors less dilute. 6·61 grains of the ignited salt yielded 5·24 grains sulphate of barytes, which is equivalent to 3·44 grains barytes. This specimen therefore consisted of

Barytes	52·04
Metaphosphoric acid	47·96
	100

which will be found on comparison to correspond very closely with the biphosphate of barytes.

The metaphosphates in general precipitate with considerable difficulty from very dilute solutions, although when once precipitated they are highly insoluble. The last washings of the metaphosphate of barytes, hot water being employed, contained no sensible trace of barytes, for they had no effect upon a sulphate. Hence the metaphosphate of barytes is an insoluble salt.

The metaphosphate of barytes may be boiled in water for two hours without sensible change; but it then begins to dissolve, and the solution proceeds at an accelerated rate, till eventually the whole disappears. The resulting solution is strongly acid, and certainly contains biphosphate of barytes, for it precipitates silver yellow. We have here, therefore, an instance of an insoluble metaphosphate passing into a soluble phosphate.

Metaphosphate of Lime.

On adding metaphosphate of soda to muriate of lime in excess, a precipitate appears like what occurs on throwing into water a solution of an essential oil in alcohol. A transparent semi-fluid body of the consistency of pitch collects at the bottom, which is a hydrate of the metaphosphate of lime in the liquid form, but insoluble in water. This salt appears to have occurred to Berzelius, and is described in his paper on the phosphates*. He formed it by precipitating muriate of lime by metaphosphoric acid, but did not observe the circumstances necessary to insure the success of the process.

IV. *Of the Modifications of Phosphoric Acid.*

The distinctive character of phosphoric acid which exists in common phosphate of soda, as compared with the other modifications, is a disposition to form salts which contain three atoms of base to the double atom of acid. Of these salts the most remarkable is the yellow subphosphate of silver, which the soluble phosphates precipitate when added to nitrate of silver. This acid does not affect albumen; and the other modifications pass directly into the condition of this acid on keeping their aqueous solutions for some days, and more rapidly on boiling these solutions; or upon fusing the other modifications or their salts with at least three proportions of fixed base.

Pyrophosphoric acid, or the acid which exists in the fused phosphate of soda, is remarkably disposed to form salts having two atoms base, which is the constitution of the white pyrophosphate of silver, formed on testing the pyrophosphate of soda with a salt of silver. Such salts of the preceding acid as contain no more than two atoms of fixed base, pass into pyrophosphates when heated to redness. The acid under consideration, when free, does not disturb albumen, nor produce a precipitate in muriate of barytes.

The metaphosphoric acid is disposed to form salts which contain one atom of base to the double atom of acid. The other modifications pass into metaphosphoric acid when heated to redness per se, or when heated to redness in contact with no more than one atomic proportion of certain fixed bases, such

* Annales de Chimie et de Physique, tom. ii. p. 172.

as soda. This acid, when free, occasions precipitates in solutions of the salts of barytes and of most of the other earths and metallic oxides, and forms an insoluble compound with albumen. The glacial or metaphosphoric acid appears to be capable of dissolving in general only about four fifths of the quantity of carbonate of soda which it can decompose when converted into phosphoric acid. But a large quantity of the meta-acid passes into phosphoric acid on uniting with the alkali, and the solution deposits phosphate of soda in tufts composed of fine crystalline plates of a silky lustre. The salt presented itself of this appearance, it will be remembered, in the case of a solution of phosphate of soda which had been boiled for a long time in a glass vessel. The liquid about the crystals, in the present case, still contained metaphosphoric acid.

Now it is a matter of certainty that if we take one combining proportion of any modification of phosphoric acid, and fuse it with soda or its carbonate, we shall form a metaphosphate, a pyrophosphate, or a phosphate, according as we employ one, two, or three proportions of base. The acid when separated from the base will possess, and retain for some time, the characters of its peculiar modification. It would appear, therefore, that the acid is impressed with a disposition to form different classes of salts by the proportion of base to which it has been united, and that it retains this disposition even when liberated from the original compound. But I suspect that the modifications of phosphoric acid, when in what we would call a free state, are still in combination with their usual proportion of base, and that that base is water. Thus the three modifications of phosphoric acid may be composed as follows:

Phosphoric acid . . . . . $\dot{H}^3\dddot{P}$

Pyrophosphoric acid . . . . . $\dot{H}^2\dddot{P}$

Metaphosphoric acid . . . . . $\dot{H}\dddot{P}$;

or they are respectively a terphosphate, a biphosphate, and phosphate of water. Now, when one of these compounds is treated with a strong base, the whole or a part of the water is supplanted, *but the amount of base in combination with the acid remains unaltered.* There are thus three sets of phosphates, in which the oxygen in the acid being five, the oxygen in the base is three, two, and one. The constitution of the acids and of the salts of soda which they form, is exhibited in the following Table.

		Oxygen in Soda.	Water.	Acid.
First Class.	Phosphoric acid	0	3	5
	Biphosphate of soda	1	2	5
	Phosphate of soda	2	1	5
	Subphosphate of soda	3	0	5
Second Class.	Pyrophosphoric acid	0	2	5
	Bipyrophosphate of soda	1	1	5
	Pyrophosphate of soda	2	0	5
Third Class.	Metaphosphoric acid	0	1	5
	Metaphosphate of soda	1	0	5

The hypothetic composition of the acid hydrates may also be stated as follows:

	Acid.	Water.
Phosphoric acid	100	37·81 = 3 atoms.
Pyrophosphoric acid	100	25·21 = 2 ——
Metaphosphoric acid	100	12·61 = 1 atom.

By a heat of 300° a dilute solution of phosphoric acid in a platinum crucible concentrates readily till the water is reduced to the proportion of three atoms, at which stage the acid assumes a dark colour, and is of the consistence of treacle when cold, but much more fluid when hot. In this condition the acid gives an unmixed yellow precipitate with silver, and is entirely phosphoric acid. By exposure for seven days over sulphuric acid in the vacuum of an air-pump, the water was reduced to 43·5 parts, and almost the whole of the acid had crystallized in thin plates, which were deliquescent in the extreme, and which there is every reason to believe were the terhydrate. By a protracted exposure to 300° or 320°, the acid continues to lose water, but much more slowly. At 460° the water was quickly reduced to 34·4 parts, or little more than 2$\frac{1}{2}$ atoms, in an experiment conducted in an open crucible, and the acid now precipitated silver white with a trace of yellow; but when neutralized by carbonate of soda, it afforded crystalline plates of phosphate of soda, among which no crystals of pyrophosphate existed. But it may be deemed possible from this result that a hydrate of phosphoric acid exists, containing 2$\frac{2}{3}$ atoms water to 1 atom acid, which is 8 atoms base to 3 atoms acid, the proportion of base to acid in the salt termed by Berzelius, the phosphate of

lime of bones. In another case in which the evaporation was conducted much more slowly in a platinum flask, the above compound was certainly not formed; but the evaporation at 415°, after advancing for several days, seemed to cease entirely when the water was reduced to 29·9 parts, which is very nearly $2\frac{1}{3}$ atoms of water. Acid at this degree of concentration, neutralized as usual by ammonia, gave, with silver, a chalky white precipitate without a shade of yellow, which suggests the idea that an acid hydrate of $2\frac{1}{3}$ water may exist, having a corresponding silver salt. Acid, so far concentrated, when neutralized by carbonate of soda, afforded a mixture of crystals of phosphate and pyrophosphate of soda, in which the latter predominated. For the production of metaphosphoric acid, the concentration of a much higher temperature was requisite; but this acid was observed to appear before the proportion of water had fallen under 2 atoms, namely, when it amounted to 28·05 per cent. in one experiment. By the greatest heat of the sand-bath, which was considerably above the melting point of lead, the proportion of water was reduced a little under 2 atoms, namely, to 22·99 parts; and the acid then contained abundance of metaphosphoric acid, as evinced by its power to coagulate albumen. In the glacial phosphoric acid, Dulong found 100 acid united with 20·6 water, and Rose 100 acid with only 10·42 water. The latter determination falls short of 1 atom water, and would indicate that phosphoric acid may be rendered partially anhydrous by heat. I do not enter upon the details of my experiments on the hydrates of phosphoric acid, as the subject is difficult, and requires a much more minute investigation than I have as yet had it in my power to give it.

Although of opinion that there is only one phosphoric acid, and that the modifications are entirely due to the quantity of water combined with the acid, I have still retained the names which have come into use, and even proposed a third, *meta*phosphoric acid, implying merely that the acid to which this name is applied is phosphoric acid with something else, namely, with an atom of water. As the classes of salts which the acid hydrates form are quite distinct, these trivial names are practically convenient, and may be adopted provisionally till chemists are prepared, by an extended knowledge of the salts, to innovate upon their nomenclature with more advantage than can be done at present.

I may be allowed to state, before concluding, that the binarseniate of soda does not appear to undergo the same remarkable changes as the biphosphate; at least, after being exposed to heat of various degrees of intensity, it continued to give the usual brown subarseniate, with nitrate of silver. But arsenic acid exhibits a weaker affinity for water than phosphoric acid, and is readily made anhydrous by heat.

XIV. *On the influence of Colour on Heat and Odours.* By JAMES STARK, *M.D., of Edinburgh.* *Communicated by Sir* DAVID BREWSTER, *K.H. F.R.S.*

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THE influence which Colour exerts upon natural bodies has hitherto been little attended to by scientific inquirers; and notwithstanding the advanced state of science in kindred departments of research, the subject of Colour, in its more interesting relations, is nearly unknown. Though BOYLE, FRANKLIN, Count RUMFORD, Sir HUMPHRY DAVY, and Sir JOHN LESLIE, have incidentally noticed some of the effects of Colour in their investigations into the nature of heat, it does not appear that it had occurred to any of those eminent men to trace its general relations; and even in regard to heat, the inquiries of Count RUMFORD and Sir JOHN LESLIE, the latest investigators, seem to have unaccountably stopped short while a wide field of unknown properties lay in view.

PART I.

ON THE INFLUENCE OF COLOUR ON HEAT.

THE singular property of a black surface to absorb light and heat has been noticed in various forms, from the time of DESCARTES downwards. BOYLE made some experiments on light, in which colour was an element*; Sir ISAAC NEWTON demonstrated the different refrangibility of the differently coloured rays of the spectrum; and Sir WILLIAM HERSCHEL observed the different heating powers of the sun's rays on the coloured eye-glasses of his telescope†. Dr. WATSON applied the knowledge of the absorbent quality of a coating of black to the bulb of the thermometer in 1772‡, and suggested that the pri-

* BOYLE's Works, by BIRCH, vol. i. p. 725. London, 1772.

† Philosophical Transactions, 1800.

‡ Philosophical Transactions abridged, vol. xiii. p. 371.

mary colours might have different powers of receiving and retaining heat and light; but he made no experiments to verify his conjecture. Count Rumford, in 1792, published a series of interesting experiments, instituted with the view of ascertaining the cause of the conducting and non-conducting powers of bodies in regard to heat*; and another series of experiments by the same philosopher, chiefly made with hollow cylinders covered with various substances, was laid before the Royal Society in 1804. The result of these experiments was, "that those substances which part with heat with the greatest facility or celerity, are those which acquire it most readily or with the greatest celerity†." The effect of colour, as a modifying principle, except as to the black coating, was neither suspected nor put to the test of experiment.

Sir John Leslie followed out the idea of the absorption of heat by a blackened ball, and fabricated some ingenious instruments on this principle. Sir John, however, though struck with the results of his experiments, rather inconsistently concludes, that "on the whole it appears exceedingly doubtful if any influence of that sort can be justly ascribed to colour. But," says he, "the question is incapable of being positively determined; since no substance can be made to assume different colours without at the same time changing its internal structure‡."

The only experiments of which I am aware, in which colour was proved to have a modifying effect upon the absorption of heat, were made by Dr. Franklin with coloured pieces of cloth laid out in sunshine upon the surface of the snow§; and by Sir Humphry Davy, with coloured pieces of copper, in 1799. Six pieces of copper variously coloured, with a small portion of cerate on their under surface, were exposed on a white board to the rays of the sun, and the time of the cerate melting noted. The result was nearly the same as in Dr. Franklin's experiment with pieces of coloured cloth. Sir Humphry did not pursue the investigation further, though in one of his works he distinctly states it as probable, that the colour of bodies is connected with their power of absorbing heat‖.

* Count Rumford's Essays, vol. ii. p. 430. London, 1798.
† Philosophical Transactions, 1804, pp. 95, 96. ‡ Essay on Heat, p. 95.
§ Franklin's Works, vol. ii. p. 109. London, 1806.
‖ Elements of Chemical Philosophy, vol. i. London, 1802.

The writers on chemistry, since the date of Sir HUMPHRY DAVY's work, merely mention the subject in terms similar to his. Dr. TURNER, indeed, is of opinion, that it remains to be proved whether any effect in the absorption of non-luminous caloric can be attributed to colour*; and Dr. THOMAS THOMSON, in his late work, says, that "hitherto it has been impossible to ascertain the efficacy of hardness and softness, and of colour upon the radiation of heat†."

I am far from thinking that the experiments now to be detailed will solve all the phenomena observed where colour may be supposed to influence the results. All I maintain is, that colour exercises a powerful influence over the absorption and radiation of caloric, both luminous and non-luminous. Future experiments may determine the extent of this modifying principle, which, till now, has been doubted or denied by most of the writers who have alluded to the subject.

Fig. 1.

I. *On the Absorption of Heat by differently coloured substances.*

Previous to detailing the experiments, it may be necessary for me to describe the apparatus employed. I took a very accurate thermometer by LOVI, graduated on the tube, which was kindly lent me by Dr. CHRISTISON. The substances to be experimented upon, when of wool, silk, or cotton, were wrapped round the bulb of the thermometer, and the thermometer then placed in a glass tube about three quarters of an inch diameter, and about nine inches long. The tube was then plunged into boiling water, and the time which elapsed during the rise of the thermometer from one given point to another accurately ascertained. The thermometer in all the experiments stood at 50° before being plunged into the boiling water, and was allowed to rise to 170° FAHRENHEIT. The apparatus was, in fact, nearly the same as that used by Count RUMFORD, except that in his experiments the tube terminated in a ball to correspond with the bulb of the thermometer.

1. The first substance used was wool, variously coloured, and as

* Elements of Chemistry, 4th edition, p. 18.

† An Outline of the Sciences of Heat and Electricity, p. 147. London, 1830.

nearly as possible of the same degree of fineness. The colours used were black, dark green, scarlet, and white, thirty grains by weight of each colour.

Black wool, at 50° Fahr.,

In 30^s rose to ..... 78°
In other 30^s rose to 102
Ditto 118
Ditto 130
Ditto 138
Ditto 145
Ditto 155
Ditto 164
Ditto 170
In 4^m 30^s the temp. rose from 50° to 170°.

Dark green wool, at 50° Fahr.,

In 30^s rose to ..... 76°
In other 30^s rose to 100
Ditto 116
Ditto 128
Ditto 138
Ditto 146
Ditto 156
Ditto 164
Ditto 167
Ditto 170
In 5^m the temp. rose from 50° to 170°.

Scarlet wool, at 50° Fahr.,

In 30^s rose to ..... 74°
In other 30^s rose to 96
Ditto 112
Ditto 122
Ditto 131
Ditto 138
Ditto 146
Ditto 154
Ditto 162
Ditto 166
Ditto 170
In 5^m 30^s the temp. rose from 50° to 170°.

White wool, at 50° Fahr.,

In 30^s rose to ..... 76°
In other 30^s rose to 100
Ditto 108
Ditto 118
Ditto 128
Ditto 136
Ditto 142
Ditto 148
Ditto 154
Ditto 158
Ditto 160
Ditto 163
Ditto 165
Ditto 168
Ditto .....169·5
Ditto 170
In 8^m temp. rose from 50° to 170°.

Thus it appears from the foregoing experiments that

Black	wool rose from 50° to 170° Fahr. in	4^m 30^s
Dark green		5 0
Scarlet		5 30
White		8 0

2. In a similar experiment with the same colours, but with only twenty grains of each, the following were the results:—

Black wool, at 50° Fahr.,

In one minute rose to .....100°
In another minute to 128
Ditto.....146
Ditto.....157
Ditto.....164
Ditto.....168
In other 35^{s} to.....170

Green wool, at 50° Fahr.,

In one minute rose to ..... 98°
In another minute to 125
Ditto.....140
Ditto.....153
Ditto.....160
Ditto.....165
Ditto.....168
In other 43^{s} to.....170

Scarlet wool, at 50° Fahr.,

In one minute rose to ..... 95°
In another minute to 123
Ditto.....138
Ditto.....149
Ditto.....158
Ditto.....163·5
Ditto.....167
Ditto.....169·9
In other 3^{s} to 170

White wool, at 50° Fahr.,

In one minute rose to ..... 94°
In another minute to 118
Ditto.....130
Ditto.....142
Ditto.....154
Ditto.....160
Ditto.....165
Ditto.....169
In other 45^{s} to 170

In this experiment the

Black wool rose from 50° to 170° Fahr. in 6^{m} 35^{s}
Green ——————————— 7 43
Scarlet ——————————— 8 3
White ——————————— 8 45

3. The next set of experiments were made with the common air thermometer, graduated to tenths of an inch in a descending series. The bulb was coated with the various colours as mentioned, and heat thrown on the ball by means of planished tin reflectors, about three inches in diameter, from a gas Argand burner. At the commencement of the experiments the coloured fluid always stood at 1°. Coated with blacking from a wax candle, and the heat reflected as mentioned, the fluid descended in a mean of four experiments to . . . . . 83°

Dark brown, a mean of three experiments to 74
Orange red, ——————————— 58
Yellow, ——————————— 53
White, ——————————— 45

The dark brown colouring-matter was peroxide of lead mixed with mucilage, and laid on with a hair-pencil; the orange red was common red lead; the yellow was litharge; and the white the common white lead of the shops. These colours were adopted in order to obviate the objection that might be made if the colouring substances had been of extremely different composition.

4. In another set of experiments, where the colouring-matter was laid on in a finer coating, and the flame of the burner reduced, the colours stood thus:—

Maximum descent with blackened ball	52°
——— Prussian blue	50
——— Umber brown	47
——— Green	44
——— Orange red	44
——— Yellow	39
——— White	34

The black coating was from the smoke of a wax candle; the blue from prepared Prussian blue; the brown from the common umber of the shops; the green from a mixture of Prussian blue, litharge, and a little gamboge; the red from red lead; the yellow from litharge and gamboge; and the white from the common white lead of the shops.

Though the above experiments, particularly those with the coloured wools, do not coincide exactly in minute particulars, the general result of the whole is nearly the same as to the ratio of the absorbing powers. Minute differences, in experiments made at intervals, may be easily accounted for from the various state of aggregation of the wool, and its being placed equally all round the bulb of the thermometer. The experiments with the air thermometer are not liable to the same objection, and the mean of a number of experiments made with this instrument would afford a pretty correct estimate of the absorbent powers of different colours.

These experiments decidedly show, that colour, independently of the nature of the substance employed, has a powerful influence over the absorption of caloric. They agree in a striking manner with the results of the experiments made by Dr. Franklin and Sir Humphry Davy, upon bodies of very different qualities, as is seen by the following comparison of the order of absorbing powers.

Absorption of Heat.

Franklin, Coloured Cloths.	Davy, Coloured Metal.	Stark, Coloured Wool.	Stark, Coloured ball of Thermometer.
Black.	Black.	Black.	Black.
Deep blue.	Blue.	——	Dark blue.
Lighter blue.	——	——	Brown.
Green.	Green.	Dark green.	Green.
Purple.	——	——	——
Red.	Red.	Scarlet.	Orange red.
Yellow.	Yellow.	——	Yellow.
White.	White.	White.	White.

II. *On the Radiation of Heat by differently coloured substances.*

It has been stated as a general principle, that the radiating powers of bodies in regard to heat, bear a proportion to their absorbing powers; that is to say, that the more quickly a body is heated, the more quickly does it part with its heat. On the contrary, it is known, that bodies which are the most powerful reflectors of heat, are those which, when heated, retain that heat the longest. This has been more particularly noticed with regard to the metals, in which, by diminishing the polish of the surface, it was found that their reflecting powers were much reduced, while their power of radiating or giving out heat was increased. No experiments have, so far as I know, been made to prove the influence of colour in modifying the radiation of heat, except with regard to metal balls and cylinders coated with black.

In these circumstances, it struck me that it would be important to ascertain whether colour, which exerts an influence so powerful over the absorption of heat, might not exert an equal influence over its radiation. To ascertain this point, was now the object of my investigation; and my anticipations as to the result were fully realized, as the following experiments demonstrate. If they are not so complete as could be wished, or the best that could be devised, they prove sufficiently the general principle, and may pave the way for more accurate investigations.

1. The first experiments which I made on the radiation of caloric, were with wools differently coloured. The colours were black, red, and white, of each

thirty grains weight. Having rolled each round the bulb of the thermometer, as formerly described, and placed them in the tube, it was heated in boiling water to the temperature of about 190°; and when the mercury in the thermometer began to descend, and had fallen to 180° Fahr., it was plunged into water at 45°, and the rate of cooling accurately noted. The following were the results:—

Black wool, at 180° Fahr.,	Red wool, at 180° Fahr.,	White wool, at 180° Fahr.,
In 60ᵐ temp. fell to 121°	In 60ᵐ temp. fell to 154°	In 60ᵐ temp. fell to 158°
In other 60ᵐ to 106	In other 60ᵐ to 137	In other 60ᵐ to 140
Ditto 95	Ditto 125	Ditto 128
Ditto 85	Ditto ..... 115·5	Ditto 116
Ditto ..... 79·5	Ditto 105	Ditto 107
Ditto ..... 74·7	Ditto 98	Ditto 98
Ditto ..... 66·7	Ditto 92	Ditto 92
Ditto ..... 63·7	Ditto ..... 86·5	Ditto 86
Ditto ..... 61·5	Ditto 82	Ditto 82
Ditto ..... 59·5	Ditto 78	Ditto 78
Ditto 58	Ditto 75	Ditto 74
Ditto ..... 56·3	Ditto 72	Ditto 71
Ditto ..... 55·7	Ditto ..... 69·3	Ditto 68
Ditto ..... 54·2	Ditto 67	Ditto ..... 65·5
Ditto ..... 53·5	Ditto 65	Ditto ..... 63·5
Ditto ..... 52·7	Ditto 63	Ditto ..... 61·7
Ditto 52	Ditto ..... 61·5	Ditto 59
Ditto ..... 51·5	Ditto ..... 59·5	Ditto ..... 57·7
Ditto 51	Ditto 58	Ditto ..... 56·5
Ditto ..... 50·5	Ditto 56	Ditto 55
Ditto 50	Ditto 55	Ditto ..... 54·2
	Ditto 54	Ditto ..... 53·3
	Ditto 53	Ditto ..... 52·5
	Ditto 52	Ditto ..... 51·7
	Ditto 51	Ditto 51
	Ditto 50	Ditto ..... 50·5
		Ditto 50

So that it appears the temperature fell in much the same ratio as it rose in the former experiments, with the same substances.

Black	wool fell from 180° to 50° Fahr. in	21ᵐ 0ˢ
Red	——————————	26 0
White	——————————	27 0

Another experiment with black, red, and white wools, twenty grains of each, and with the temperature at 173°, gave the following results:—

Black wool, at 170° Fahr.,	Red wool, at 170° Fahr.,	White wool, at 170° Fahr.,
In 60″ temp. fell to 128°	In 60″ temp. fell to 140°	In 60″ temp. fell to 140°
In other 60″ to 117	In other 60″ to 124	In other 60″ to 128
Ditto 104	Ditto 112	Ditto 115
Ditto 93	Ditto 105	Ditto 106
Ditto 86	Ditto 98	Ditto 99
Ditto 80	Ditto 89	Ditto 92
Ditto 77	Ditto 85	Ditto 89
Ditto 74	Ditto 80	Ditto 84
Ditto .... 71·5	Ditto 76	Ditto 80
Ditto .... 69·5	Ditto .... 73·5	Ditto 76
Ditto .... 67·5	Ditto 70	Ditto 74
Ditto .... 65·7	Ditto 68	Ditto 71
Ditto 64	Ditto 66	Ditto 69
Ditto .... 62·7	Ditto 64	Ditto 67
Ditto 61	Ditto .... 62·5	Ditto 65
In other 45″ to 60	Ditto 61	Ditto .... 63·5
	Ditto 60	Ditto 62
		Ditto .... 60·5
		In other 30″ to 60

Black wool fell from 170° to 60° Fahr. in	15m	45″	
Red	17	0	
White	18	30	

The next experiments were made with wheat flour, coloured black, brown, yellow, and white. The black colouring-matter was lamp-black; the brown was the umber of the shops; and gamboge powder was the yellow. I took one hundred grains of each coloured flour, and placed them separately in a tube of about three quarters of an inch in diameter; then sunk the bulb of the thermometer into the middle of the flour, and heated the tube in boiling water to about 190° Fahrenheit. When the mercury began steadily to descend and arrived at 180°, I plunged the tube into water at 45°, and observed the rate of cooling. The following were the results:—

Black flour, at 180° Fahr.,

In 60ˢ the temp. fell to	142°
In other 60ˢ to	110
Ditto	91
Ditto	78
Ditto	68
Ditto	62
Ditto	57
Ditto	54
Ditto	52
In other 50ˢ to	50

Brown flour, at 180° Fahr.,

In 60ˢ the temp. fell to	142°
In other 60ˢ to	114
Ditto	96
Ditto	84
Ditto	74
Ditto	66
Ditto	60
Ditto	56
Ditto	54
Ditto	52
Ditto	50

Yellow flour, at 180° Fahr.,

In 60ˢ the temp. fell to	145°
In other 60ˢ to	119
Ditto	99
Ditto	85
Ditto	75
Ditto	67·5
Ditto	62
Ditto	57·5
Ditto	55
Ditto	52·5
Ditto	51
Ditto	50

White flour, at 180° Fahr.,

In 60ˢ temp. fell to	148°
In other 60ˢ to	122
Ditto	102
Ditto	88
Ditto	78
Ditto	69
Ditto	64
Ditto	58
Ditto	56
Ditto	54
Ditto	52
Ditto	50·3
In other 15ˢ to	50

Thus, Black flour fell from 180° to 50° Fahr. in 9ᵐ 50ˢ

Brown	11	0
Yellow	12	0
White	12	15

A third set of experiments was made by coating the ball of the air-thermometer with various pigments as described; and having heated the ball till it descended to 100° on the scale, the rise of the coloured fluid was accurately noted. The results were as follows:—

Black ball, at 100° Fahr.,
(Coloured from smoke of wax candle,)

In 60^s rose to	21°
In other 60^s rose to	2
In other 2^s to	1

Second Experiment.

In 60^s rose to	20°
In other 60^s to	2
In other 3^s to	1

Brown ball, at 100° Fahr.,
(Coloured with peroxide of lead,)

In 60^s rose to	27°
In other 60^s to	6
In other 40^s to	1

Second Experiment.

In 60^s rose to	28°
In other 60^s to	6
In other 40^s to	1

Orange-red ball, at 100° Fahr.,
(Coloured with red lead,)

In 60^s rose to	34°
In other 60^s to	12
Ditto	3
In other 45^s to	1

Second Experiment.

In 60^s rose to	34°
In other 60^s to	13
Ditto	3
In other 44^s to	1

Yellow ball, at 100° Fahr.,
(Coloured with litharge and gamboge,)

In 60^s rose to	33°
In other 60^s to	13
Ditto	5
Ditto	2
In other 28^s to	1

Second Experiment.

In 60^s rose to	34°
In other 60^s to	14
Ditto	6
Ditto	2
In other 30^s to	1

White ball, at 100° Fahr.,
(Coloured with white lead,)

In 60^s rose to	40°
In other 60^s to	21
Ditto	9
Ditto	6
Ditto	2
In other 50^s to	1

Second Experiment.

In 60^s rose to	41°
In other 60^s to	21
Ditto	9·5
Ditto	7
Ditto	2·5
In other 51^s to	1

These experiments demonstrate that differently coloured substances possess a specific influence on the absorption of heat or caloric, both luminous and non-luminous; and that they give off their caloric in the same ratio as they absorb it.

The experiments may be varied to any extent, by using different substances; and even water in coloured vessels cools more or less quickly, according to the colour of the vessel in which it is held. For instance, to ascertain this, I filled glass balls about an inch and a quarter in diameter with water at 120° Fahr., and placed a thermometer in the fluid. The time which elapsed during the fall of the mercury through 25° was accurately noted, and the results were,

that the ball coated with Prussian blue fell through that interval in seventeen minutes; the ball coated with orange red in eighteen minutes; and that coated with white in nineteen minutes. The temperature of the air in the room was 50°.

The demonstration of the influence of colour on the absorption and radiation of caloric, may tend to open up new views of the economy of Nature, and perhaps suggest useful improvements in the management and adaptation of heat. Dr. Franklin*, who never lost sight of practical utility in his scientific investigations, from the result of his experiments with coloured cloths on the absorption of heat, drew the conclusion, "that black clothes are not so fit to wear in a hot sunny climate or season as white ones, because in such clothes the body is more heated by the sun when we walk abroad and are at the same time heated by the exercise; which double heat is apt to bring on putrid, dangerous fevers;" that soldiers and seamen in tropical climates should have a white uniform; that white hats should be generally worn in summer; and that garden walls for fruit trees would absorb more heat from being blackened.

Count Rumford and Sir Everard Home, on the contrary, come to a conclusion entirely the reverse of this. The Count asserts, that if he were called upon to live in a very warm climate, he would blacken his skin or wear a black shirt; and Sir Everard, from direct experiments on himself and on a negro's skin, lays it down as evident, "that the power of the sun's rays to scorch the skins of animals is destroyed when applied to a dark surface, although the absolute heat, in consequence of the absorption of the rays, is greater†." Sir Humphry Davy explains this fact by saying, "that the radiant heat in the sun's rays is converted into sensible heat." With all deference to the opinion of this great man, it by no means explains why the surface of the skin was kept comparatively cool. From the result of the experiments detailed, it is evident, that if a black surface absorbs caloric in greatest quantity, it also gives it out in the same proportion; and thus a circulation of heat is as it were established, calculated to promote the insensible perspiration, and to keep the body cool. This view is confirmed by the observed fact of the stronger odour exhaled by the bodies of black people.

* Dr. Franklin's Works, vol. ii. p. 109. London, 1806.

† Philosophical Transactions, 1821, p. 6.

The different shades of colour by which races of men inhabiting different climates are distinguished, equally possess, there is reason to believe, the quality of modifying the individual temperature, and keeping it at the proper mean. This adaptation of colour may perhaps be traced in the inhabitants of every degree of latitude, and be found to correspond with the causes which limit the range of plants and animals. The effect of exposure to the sun in our own country in warm seasons, is temporarily to change the colour of the parts submitted to its influence, and to render them less susceptible of injury from the heating rays.

The influence of colour as modifying the effects of heat, is also strikingly illustrated in other classes of the animal kingdom. The quadrupeds, for instance, which pass the winter in northern latitudes, besides the additional protection from cold they receive in the growth of downy fur, change their colour on the approach of the cold season. The furs of various hues which form their summer dress are thrown off, and a white covering takes its place. Hence the white foxes, the white hares, and the ermine of the arctic regions. Even in more temperate climates, and in our own country, the hare in severe winters often acquires a white fur; and the stoat, or ermine, is found with its summer dress more or less exchanged for a winter clothing of pure white. Some writers on natural history state these changes as means of protection to the animals from their enemies, by assimilating their colour to the winter snow. Without denying that this may be one cause for the periodical change of colour, I am rather disposed to consider it as accommodating the animal to the changes of season it undergoes. The white winter coating, as is evident from the experiments detailed, does not throw off heat so rapidly as any of the other colours; and hence its use in preserving the animal temperature.

The feathered tribes which inhabit northern latitudes afford still more remarkable instances of the adaptation of colour to the changes of temperature. The summer dress of many families is so different from their winter plumage as to have led many ornithologists to multiply species, as the animal was described in its winter or summer plumage. The ptarmigan is a familiar example. Mr. Selby remarks, that "the black deep ochreous yellow plumage of the ptarmigan in spring and summer gradually gives place to a greyish white; the black spots become broken and assume the appearance of zigzag lines

and specks. These again, as the season advances, give place to the pure immaculate plumage which distinguishes both sexes in winter*."

The display of colours in the plumage of the birds of tropical climates is also in strict accordance with the observed facts of the influence of colour over the absorption and radiation of heat. The metallic reflexions and polished surface of the whole family of humming-birds is admirably suited to their habits; and the colours of the wings of the Lepidoptera, in the class of insects, there is little doubt, serve some similar purpose, in maintaining the temperature of the animals at the proper mean. In proportion to the diminution of temperature and the distance from the equator, a corresponding dilution of colour in animals takes place, till in temperate countries it is almost uniformly of a sober gray. In the arctic regions all colour except white and black disappears,—modifications of which, with very little variety of other colours, form the summer and winter clothing of most of the northern tribes of birds.

In the vegetable kingdom, I am disposed to believe that the colours of the petals of flowers serve some useful purpose in regard to preserving the temperature of the parts necessary for reproduction at the proper mean; and that the varied pencilling of Nature has thus an object beyond merely pleasing the eye. In this view, the quality of colour, so widely extended and so varied and blended in every class of natural bodies, acquires a further interest in addition to its ministering to the pleasures of sight, and affords a new instance of that benevolence and wisdom by which all the arrangements of matter are calculated to excite and gratify the mind directed to their investigation.

Even in the inorganic portion of Nature, and in northern climates, the portion of heat imbibed by the soil during a short summer is prevented from escaping by the covering of snow which falls in the beginning of winter; and thus the temperature necessary for the scanty vegetation is kept up. By this white covering vegetables are enabled to sustain a lengthened torpidity without suffering from the injurious effects of frost; and the ground is preserved from partial alternations of temperature, till the influence of the sun at once converts the northern winter into summer without the intervention of spring.

* Selby's Illustrations of British Ornithology, Part I. p. 312.

On the influence of Colour on the deposition of Dew.

As connected with the preceding investigations, it may be mentioned, that I had projected a train of experiments to ascertain the proportions in which dew was deposited on variously coloured substances. Dr. Wells found the deposition of dew influenced by the radiating power of the substance employed; but neither he nor any of the philosophers who have treated of the subject seem to have been aware of the modifying effects of colour on the absorption and radiation of Heat. My avocations have hitherto prevented me from following out these experiments; but to show that the influence of colour may be extended to moisture, and of course to Dew, I shall give from my notes the result of two experiments made to ascertain this point.

January 16, 1833.—I exposed last night (the temperature ranging from 28° to 30°, and with a dense fog,) ten grains of black wool, the same quantity of scarlet wool, and an equal weight of white wool, on a black board, which was placed on the leads on the top of the house. When taken in this morning and carefully weighed, the

Black wool had gained	32 grains.
Scarlet wool	25 ——
White wool	20 ——

deposited on the wool in the form of hoar frost.

A few nights afterwards, after a slight thaw, and when towards night the temperature fell to 31°, I again exposed four colours of wool, ten grains of each, in the same manner. By next morning the

Black wool had gained . . .	10 grains.
Dark green	$9\frac{5}{10}$ ——
Scarlet	6 ——
White	5 ——

Dr. Wells had indeed made experiments on the deposition of dew with equal quantities of black and white wool; and in four out of five experiments, the black wool was found to have acquired a little more dew than the white; "whence," says he, "I concluded that it had also radiated a little more heat. But I afterwards remarked, that the white wool was somewhat coarser than

the black, which might have occasioned the difference of their attraction for dew." On another night he made an experiment with pasteboard covered with white paper, and pasteboard covered with paper blackened with ink. "At daylight," says he, "I observed hoar frost upon both pieces, but the black seemed to have a greater quantity than the white*."

These facts, it might have been supposed, would have led Dr. Wells to further experiments with different colours. But the reverse was the case. He quotes Mr. Leslie as to the hopelessness of success, without making a further attempt; "since a black body almost always differs from a white in one or more chemical properties, and this difference may alone be sufficient to occasion a diversity in their powers of radiating heat."

PART II.

ON THE INFLUENCE OF COLOUR ON ODOURS.

If the influence of colour over heat attracted but little the attention of philosophers employed in the investigation of the absorbing and radiating powers of different substances, even when presented to their notice in anomalous facts, which could not easily be explained on any other principle, it is not to be wondered at, that the apparently far less appreciable influence of Colour on Odours should have totally escaped notice. In point of fact, I am not aware that the subject has hitherto been investigated, and know of no recorded facts in which the influence of colour over odours has been pointed out. In attempting to show from experiment that the colour of bodies in imbibing odours is correlative with the power of colour over the absorption and radiation of heat, I state a fact which, though new to science, is in admirable correspondence with the known properties of light and heat. And though I may not be able, from the nature of the substances subjected to experiment, absolutely to determine the amount of this connexion, I trust my imperfect investigations may form the basis of new and better devised experiments, by directing the attention of men of science to this hitherto untrodden field of inquiry.

* Wells on Dew, p. 106. London, 1814.

My attention was first directed to the subject of odours, as connected with colour, during my attendance at the anatomical rooms in the winter session 1830–1831. During the earlier part of that winter I generally wore a light olive-coloured dress; but happening one day to attend the rooms in black clothes, I was not a little struck by the almost intolerable smell they had acquired. The smell was so very strong as to be remarked even by the family at home, and it was recognised on the same piece of dress for several days. No odour to the same extent had been remarked in the lighter-coloured clothes. The fetid smell which they more or less acquired in the atmosphere of the rooms was comparatively trifling, and slight exposure to the air alone was necessary to deprive them of the odour which they had thus contracted.

This circumstance led me to begin a series of experiments, to ascertain, if possible, why different cloths of nearly the same texture, but not of the same colour, should attract odours in proportions so very different. The result was, as I had ventured to conjecture, that the colour of bodies, independent of the nature of the substance, modifies in a striking manner the capability of surfaces for imbibing and giving out odours.

1. I inclosed black and white wool, ten grains of each, in a vessel with a small piece of camphor, and kept it carefully secluded from the light. When examined six hours afterwards, it was at once evident to the sense of smell that the black wool had attracted more of the odorous particles than the white wool, though neither had gained any appreciable weight.

2. I took equal weights of black and white wool, and put them in a small drawer along with a piece of assafœtida; in twenty-four hours the black wool had contracted a strong odour of the gum, while in the white wool, the smell was scarcely perceptible.

3. To try the effect of odours upon a vegetable substance, I took equal quantities of black and white cotton wool, and inclosed them with assafœtida. Two similar quantities were at the same time exposed to the emanations of camphor in another drawer. In both the black-coloured cotton had attracted the greatest quantity of odorous particles, as palpably evidenced by the smell.

These experiments were made in the month of April 1831; but it was not till August following that I had an opportunity of extending the investigation to other colours.

4. I inclosed equal weights of black, red, and white wool, in a drawer with assafœtida; and similar quantities of these coloured wools in another drawer with camphor. The result was as before. The black in both experiments had attracted by far the greatest quantity of odorous particles, as evidenced to smell; the red next followed in point of intensity of smell; and the white, so far as could be judged, had attracted least of the odour.

5. The same experiments were tried on cotton of similar colours, and with the same results.

Circumstances prevented me from resuming these investigations till the summer of 1832, when I repeated the experiments with a greater variety of coloured substances, in wool, cotton, and silk, and satisfied not only myself but many of my friends, that odour was attracted nearly in the same ratio as caloric, by coloured substances. The experiments were conducted in the same manner as the preceding.

6. I inclosed six different-coloured wools, an equal weight of each, viz. black, blue, green, red, yellow, and white, with assafœtida. They were ranged circularly round the odorous body, without touching it or one another, and were then covered over and excluded from the light. At the end of twenty-four hours they were examined. The black was found to have much the strongest smell of assafœtida; the blue the next; after that the red, and then the green; the yellow had but little smell, and the white scarcely any.

7. A similar experiment, using camphor instead of assafœtida, afforded precisely the same results.

8. Various coloured cottons were treated in the same manner. In all these the smell was invariably found to be of corresponding intensity, according to the colour, as in the wools.

9. Silks of different colours gave the same results.

10. I next endeavoured to ascertain the comparative power of vegetable and animal substances, so far as regards their influence over odours. This was a much more delicate point to ascertain with sufficient accuracy, and free from fallacy, as it was difficult to obtain wool of the same degree of fineness as cotton, the substances I generally preferred for these experiments. I first inclosed equal weights of black and white wool, and black and white cotton,

with camphor. After twenty-four hours, the black wool had acquired a stronger smell than the cotton of similar colour; the white wool had also taken up more of the odorous particles than the white cotton, though the odour in both was very feeble.

11. When assafœtida was used in a similar experiment, the odour was much more distinguishable, and it could at once be distinguished by smell, that the wool had taken up much more of the odour than the cotton. Indeed, from many experiments I have made to ascertain this fact, wool appears to have a peculiar attraction for fetid odours. For instance, if, after having allowed wool to lie in contact with camphor for some time, it be afterwards placed, even for a very few hours, near a minute portion of sulphuret of barium (which, it is well known, exhales copiously the fetid odour of sulphuretted hydrogen,) it quickly loses the camphorous smell, and acquires and even retains in considerable intensity the fetid smell of the sulphuret.

It is proper to mention, that in most of these experiments I did not trust to my own olfactory organs alone. All the members of the family, and several of my friends, have lent their aid to distinguish between the different intensities of the odour which each substance had attracted; and though only a few experiments are here detailed, similar ones have been many times performed, with various other odorous substances. The whole of these in their general results seemed to establish the fact, that the colour of substances exerted a peculiar influence over the absorption of odours.

In all these experiments, however, reliance had to be placed upon one sense alone, viz. that of smell, as none of the substances employed had gained any appreciable weight. I was therefore desirous, that, if possible, at least one experiment should be devised, which would show, by the evidence of actual increase of weight, that one colour invariably attracted more of any odorous substance than another; and upon considering the various odorous substances which could be easily volatilized without change, and whose odour was inseparable from the substance, I fixed upon camphor as the one best suited to my purpose. In an experiment of this nature, it was necessary that the camphor should be volatilized or converted into vapour, and that the coloured substances should be so placed as to come in contact with the camphor while in that state. It was therefore of the first importance to prevent currents of air

within the vessel in which the experiment was conducted; and with this view I used a funnel-shaped vessel of tin plate, open at the top and bottom, of the form represented in fig. 2. This rested on a plate of sheet iron, in the centre of which the camphor to be volatilized was placed. The coloured substances, after being accurately weighed, were supported on a bent wire (as shown in the section fig. 3.), and introduced through the upper aperture. This was then covered over with a plate of glass. Heat was now applied gently to volatilize the camphor; and when the heat was withdrawn and the apparatus cool, the coloured substances were again accurately weighed, and the difference in weight noted down.

Fig. 2. Fig. 3.

Proceeding on this plan, I arrived at the most satisfactory and conclusive results. The deposition of the camphor in various proportions on the coloured substances submitted to experiment, offered evidence of the particular attraction of colours for odours, resting on ocular demonstration; and when to this is added the evidence arising from a positive increase of weight, as ascertained by the balance, the conclusions previously drawn from the sense of smell are confirmed in a singular and very satisfactory manner. I have in this mode repeated all the former experiments with differently coloured substances; but shall here only detail a few, as sufficient to show the general results.

1. I took ten grains of white, and the same quantity of black wool, and having suspended them in the manner stated, vaporized the camphor. When the apparatus cooled, I found on weighing the wool, that the white had gained $1\frac{5}{10}$ grain in weight, and the black $1\frac{8}{10}$ grain.

2. In a similar experiment, but using three colours of wool, white, red, and black, I found the white wool had gained $\frac{3}{10}$ths of a grain; the red $\frac{8}{10}$ths; and the black $1\frac{4}{10}$ grain.

3. In another, where the heat was applied for about ten seconds, the white had gained no appreciable weight, and but little smell; the red had gained $\frac{1}{3}\frac{1}{0}$th of a grain; while the black had acquired $\frac{8}{10}$ths of a grain.

4. In an experiment with black, red, green, and white wool, the results were:—

Black gained	$\frac{8}{10}$ grain.
Red	$\frac{3}{10}$ ——

Green gained . . . . . $\frac{2 \cdot 5}{1 0}$ ——
White . . . . . $\frac{1}{1 0}$ ——

5. In an experiment with wools of nearly the same fineness, coloured black, blue, red, green, and white, ten grains of each, exposed to the vapour of camphor, the result stood thus:—

Black gained . . . . . $1\frac{9}{1 0}$ grain.
Dark blue . . . . . $1\frac{9}{1 0}$ ——
Scarlet red . . . . . 1 ——
Dark green . . . . . 1 ——
White . . . . . $\frac{7}{1 0}$ ——

In repeating this experiment the dark green was $\frac{7}{1 0}$, while the red was only $\frac{6}{1 0}$; the others in the order as before.

I now varied the experiment by employing square pieces of card of equal size, coloured with different preparations of lead. This was done with the view of ascertaining whether smooth surfaces of equal density, and coloured as nearly as possible with matter of the same nature, would absorb odorous particles with the same facility as loose portions of wool. The colours were mixed up with a solution of gum arabic, and laid on the cards as equally as possible with a camel-hair pencil.

6. Pieces of card of equal size being coloured as mentioned, with various preparations of lead, namely, red, brown, yellow, and white, and previously weighed, were exposed to the vapour of camphor in the vessel before described. After exposure for some time, and when cool, it appeared on weighing that the

Red had gained . . . . . 1 grain.
Brown . . . . . $\frac{9}{1 0}$ ——
Yellow . . . . . $\frac{5}{1 0}$ ——
White . . . . . a trace.

The whole of the upper surfaces of the red and brown cards were thickly covered with a fine light downy deposit of camphor. The white card had an extremely fine deposit on its surface, but inappreciable by the balance, which turns with the fiftieth part of a grain.

7. Another experiment with cards, coloured black, red, brown, yellow, and white, exposed to the vapour of camphor, gave the following results:—

Black gained	1 grain.
Red	$\frac{9}{10}$ ——
Brown	$\frac{7}{10}$ ——
Yellow	$\frac{5}{10}$ ——
White	$\frac{4}{10}$ ——

8. In a similar experiment with cards coloured black, dark blue, dark brown, orange red, and white, the attractive powers were as follows:—

Black gained	$\frac{9}{10}$ grain.
Dark blue	$\frac{8}{10}$ ——
Dark brown	$\frac{4}{10}$ ——
Orange red	$\frac{3}{10}$ ——
White	$\frac{1}{10}$ ——

In all these experiments it was invariably found that the black attracted most; the blue next; then followed the red and green; and after these the yellow and white. The heat was never continued so long as to warm the apparatus, else the whole camphor would have been driven off. Neither was such a quantity of camphor used as would have given a thick coating to the wool employed, as then the attraction of the coloured surfaces might have been diminished.

1. The next set of experiments were intended to ascertain the comparative attraction of animal and vegetable substances. The first of these was upon equal weights of black wool and black silk, (ten grains,) exposed to the vapour of camphor in the manner already stated. The black wool gained $1\frac{5}{10}$ grain, and the black silk $1\frac{7}{10}$ grain. From this experiment it would appear that of these two animal substances, silk possesses the greatest attraction for odours.

2. In equal weights of white wool and white cotton, the cotton had gained $\frac{3}{10}$ths of a grain, and the wool $\frac{4}{10}$ths.

3. In another experiment with white silk, white wool, and white cotton, ten grains of each, the result was:—

Silk had gained	$3\frac{5}{10}$ grains.
Wool	$2\frac{4}{10}$ ——
Cotton	$2\frac{2}{10}$ ——

4. In a similar experiment with the usual weight of the same articles,

Silk had gained	$1\frac{4}{10}$ grain.
Wool	$\frac{5}{10}$ ——
Cotton	$\frac{4}{10}$ ——

5. Another experiment, in which black silk, black wool, and black cotton were exposed, in equal quantities of the usual weight, to the vapour of camphor, as before described, gave this result:—

Black silk had gained	$\frac{8}{10}$ grain.
Black wool	$\frac{1}{10}$ ——
Black cotton	$\frac{1}{20}$ ——

6. An experiment with white silk, white wool, white cotton, and white card, each weighing ten grains, and exposed as before, gave the following results:—

White silk had gained	$1\frac{9}{10}$ grain.
White wool	$1\frac{1}{10}$ ——
White cotton	1 ——
White card	$\frac{4}{10}$ ——

The last experiments tend to show that different substances attract odours in different proportions, and this independent of the texture or fineness of the substance employed. Wool, though generally coarser in the filament than cotton, has yet a greater attraction for odours; and silk more than wool. The general conclusion would appear to be, that animal substances have a greater attraction for odours than vegetable matters; and that all these have their power much increased by their greater darkness or intensity of colour. These experiments seem also to establish, that the absorption of odours by coloured substances is regulated by the same law which governs the absorption of light and heat. The analogy goes still further; for in other experiments made with a view to ascertain this point, I invariably found, that the power of colour in radiating or giving out odours, was in strict relation to the radiation of heat in similar circumstances. My first experiments on this branch were with differently coloured wools, inclosed for a certain time in a drawer along with assafœtida and camphor, and afterwards exposed for a specific period to the action of the air. Though one can easily judge by the sense

of smell alone the different intensities which these articles have acquired immediately on being taken out of the drawer, yet, after exposure for some time to the air, the difference of intensity is much more difficult to be perceived. In general it seemed to me, that the whole of the substances lost their sensible odour in nearly the same space of time, though the odorous particles given out by the black were of course much greater in quantity than in the others.

To demonstrate this, I took pieces of card coloured, as before, black, dark blue, brown, orangered, and white, and after having exposed them to the vapour of camphor, in the usual manner, they were taken out of the vessel, weighed, and left in the apartment for twenty-four hours. Upon carefully re-weighing the cards at the end of this period, it was found that the black had lost one grain; the blue nearly as much; the brown $\frac{9}{10}$ths of a grain; the red $\frac{8}{10}$ths; and the white $\frac{6}{10}$ths of a grain. In about six hours after this the black and blue had completely lost their camphor; the brown and red had the merest trace, inappreciable to a delicate balance; while the white still retained about $\frac{1}{30}$th of a grain.

In another experiment with cards coloured dark blue, dark brown, orange red, yellow, and white, they had gained in weight, after exposure to the vapour of camphor,

Dark blue	$\frac{9}{10}$ grain.
Dark brown	$\frac{8}{10}$ ——
Orange red	$\frac{6}{10}$ ——
Yellow	$\frac{5}{10}$ ——
White	$\frac{4}{10}$ ——

After lying in the apartment for twenty-four hours, the cards were again carefully weighed, when the camphor remaining was found to be on the

Dark blue	$\frac{1}{30}$ grain.
Dark brown	$\frac{1}{10}$ ——
Orange red	$\frac{9}{10}$ ——
Yellow	$\frac{1}{10}$ ——
White	$\frac{8}{10}$ ——

Hence in the same space of time the loss in each was,

Dark blue	$\frac{26}{30}$ grain.
Dark brown	$\frac{21}{30}$ ——
Orange red	$\frac{12}{30}$ ——
Yellow	$\frac{12}{30}$ ——
White	$\frac{3}{30}$ ——

The influence of coloured surfaces upon the absorption and emission of odours, having, I trust, been satisfactorily shown, it only remains for me to state shortly some of the practical conclusions which may be drawn from the experiments detailed.

If it be thus certain that odorous emanations have not only a particular affinity for different substances, but that the colour of those substances materially affects their absorbing or radiating quality; the knowledge of these facts may afford useful hints for the preservation of the general health during the prevalence of contagious or epidemic diseases. From their minute division and vast range of action, latent poisonous exhalations or effluvia, inappreciable by the balance, may, no doubt, exist to dangerous extent without being evident to the sense of smell. But in most cases it will be found, that, when contagious diseases prevail to such extent, the emanations from the sick will, if attended to, give the surest indications of the contamination of the surrounding air.

Experience has sufficiently proved, that emanations, once generated in, or communicated to, the human body, may be conveyed from one individual to another, and even through the medium of clothing or merchandize from one place to another. This has been particularly observed in plague; and hence in countries where this disease is liable to occur or be imported, the institution of quarantine establishments, to prevent personal intercourse or the dispersion of goods till a certain number of days have elapsed, during which the disease, if existing, should appear;—articles of merchandize and clothing being at the same time purified by exposure to the air, or fumigated. Though this transport of disease has been more particularly observed in plague, yet instances of the same nature have occurred in other diseases, more particularly small-pox, and more recently, it has by many been supposed, cholera.

It is unnecessary to detail here the means of purifying infected goods, or fumigating the apartments of those who have been known or suspected to labour under diseases supposed to be communicated by contagious effluvia. It is sufficient to state, that exposure to a high temperature, fumigations with chlorine and sulphur, and free exposure to the air, are found amply sufficient for the first; and apartments are now generally recommended to be purified with chlorine, and washed with caustic lime. As to fumigation with chlorine, it cannot be denied that this will destroy the animal effluvia floating in the air exposed to its action. But unless this fumigation be frequently repeated, it can have but little effect, as the walls and furniture will be constantly contaminating the air by giving out the deleterious particles which they had previously absorbed. Lime-washing has generally been supposed to act in the same manner as fumigations, viz. by destroying the contagious emanations; but from the experiments of Guyton Morveau, it would seem, that caustic lime, and indeed lime in any state, has no such effect. It merely absorbs the gases which disguise the odour, but neither changes its deleterious properties nor alters its real smell. He therefore disregards lime-washing, except as a general mode of cleaning walls, and attributes no other beneficial effect to it than as contributing to cleanliness.

The results of my investigations have led me to form a very different opinion. It is to white-washing that I should attribute much of the good effects that have been observed to follow the purifying means generally employed. In such cases I should trust more to white-washing the walls, personal cleanliness, and free ventilation, for destroying or diminishing the effects of supposed pestilential or hurtful effluvia, than to any other measures. Acid and other fumigations, except chlorine, only disguise, but do not destroy the property of animal effluvia to produce disease.

In the late epidemic cholera here, it is well known, that this disease first broke out in the village of Water-of-Leith, situated a little to the north-west of Edinburgh, and lying on both sides of the stream of the same name. Many of the inhabitants were seized with the disease and fell victims to its severity. If a damp and low situation, with accumulated filth of all kinds, render disease more fatal, this was certainly a place likely to suffer severely, and at first it did so. But the Board of Health, with that promptitude, for which they were

distinguished, quickly got the filth, so far as practicable, removed, the houses fumigated, and the walls white-washed outside and inside. By these means the disease seemed at once to be arrested; its virulence was much abated, and it gradually declined. The fumigations in this case could only act upon the deleterious emanations in the air at the time; but unless constantly renewed could not affect the fresh emanations generated from those labouring under the disease. The necessary ventilation must also have speedily carried off the chlorine. The white-washing, on the other hand, although it had no specific action on the contagious effluvium, yet, by constantly presenting a reflecting surface, prevented the absorption of the emanations by the walls, and thus tended, with moderate ventilation, to keep the air of the apartments pure. Dirty dark-coloured walls, on the contrary, would readily, as has been demonstrated, absorb noxious odours, and as soon as the effect of the fumigation was over, gradually give them out again.

The good effects of white-washing appeared strikingly in another instance at this particular time; for I venture to assert, that, if human means had any influence over this disease, Edinburgh owes much of the mildness of its attack to the white-washing of its steep and narrow lanes and closes, the walls of the common stairs, and most of the hovels inhabited by the lowest classes of the community, and not to the partial fumigations and sprinkling with chloride of lime, which the first breath of wind carried off. The whiteness of the walls prevented them from absorbing the deleterious emanations, and the currents of air were thus enabled to sweep them away, before they had accumulated to such a degree as to become an active source of disease.

Next, therefore, to keeping the walls of hospitals, prisons, or apartments occupied by a number of individuals, of a white colour, I should suggest that the bedsteads, tables and seats should be painted white, and that the dress of the nurses and hospital attendants should be of a light colour. A regulation of this kind would possess the double advantage of enabling cleanliness to be enforced, at the same time that it presented the least absorbent surface to the emanations of disease.

On the same principle it would appear that physicians and others, by dressing in black, have unluckily chosen the colour of all others most absorbent of odorous exhalations, and of course the most dangerous to themselves and

patients. Facts have been mentioned which make it next to certain, that contagious disease may be communicated to a third person through the medium of one who has been exposed to contagion, but himself not affected*; and indeed the circumstance of infectious effluvia being capable of being carried by medical men from one patient to another, I should conceive one of the means by which such diseases are often propagated, in the ill-ventilated and dirty habitations of the poor exposed to their influence.

Even in my own very limited experience I think I have observed some melancholy instances of the effect of black dress in absorbing the hurtful emanations of fever patients in a public hospital; and many facts are incidentally related by medical writers, and referred to other causes, which I should not hesitate to ascribe chiefly to exposure of this nature. Not to mention individual cases, in the sessions held at Oxford in July 1577, "there arose amidst the people such a damp that almost all were smothered†." Lord Bacon attributes this effect to the "smell of the gaol, where the prisoners have been close and nastily kept," and mentions it having occurred twice or thrice in his time, when both the judges that sat upon the trial, and numbers of those who attended the business, or were present, sickened or died‡." A similar occurrence, related by Sir John Pringle, happened at the Old Bailey sessions in 1750, when four of the judges were attacked and died, together with two or three of the counsel, one of the under sheriffs, several of the jury, and others present, to the amount of above forty in the whole§. My explanation of the peculiar fatality of these emanations to the judges, counsel, and jurors, was the attraction of their official black for the putrid effluvium, as Sir John calls it; and the escape of two of the judges who sat on one side of the Lord Mayor, to the current of air in the room not sending the baneful odours in their direction.

* See Treatise on the Epidemic Puerperal Fever of Aberdeen, by Alexander Gordon, M.D. London, 1795.

† Stow's Chronicle.

‡ Pringle's Observations on Diseases of the Army, p. 296.

§ Ibid. p. 297.

XV. *Experimental Researches in Electro-Magnetism and Magneto-Electricity. By the Rev.* WILLIAM RITCHIE, *LL.D. F.R.S., Professor of Natural Philosophy at the Royal Institution of Great Britain and in the University of London.*

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PART I.

ON ELECTRIC CONDUCTION.

ACCORDING to the experiments of Professors CUMMING and BARLOW, the conducting power of a wire for voltaic electricity varies directly as its diameter, and inversely as the square root of its length. My own previous experiments on this subject, with all the conductors I then tried, led to the same result. According to the experiments of M. BECQUEREL, the conducting power varies directly as the square of the diameter or area of the section, and inversely as the length. M. POUILLET, from an extensive series of experiments, arrived at the conclusion that the conducting power was exactly proportional to the section of the wire, and inversely proportional to the length, increased by a constant quantity. Such discordant results, in establishing a fundamental law in electro-magnetism, obviously require a more careful examination than has yet been bestowed on them. Before we admit the accuracy of the conclusions, we must first examine the accuracy of the galvanometer employed, and the different modes of using it. The mode employed by Professors CUMMING, BARLOW, and POUILLET, was to observe the deflections of a compass needle placed over the conducting wire, and calculate the forces by assuming that the tangents of deflection were proportional to the deflecting forces. Now, when the conductor is indefinitely long, the wire very fine, the needle placed very near it, and the arcs of deflection small, the results obtained will not be very far from the truth. These conditions approach to the assumptions from which the mathematical law is deduced. But when the wire placed below the needle is short, when the diameter is considerable, and when the arcs of deflection rise to

sixty, seventy, or eighty degrees, the results calculated in this way will be found to deviate very far from the truth. When the wire is formed into a short rectangular coil, as in the common galvanometer, no numerical results can be obtained from its indications; for all the conditions assumed in the mathematical investigation are here completely violated. A single experiment will prove the truth of this assertion.

Having placed four copper wires, about four inches long, parallel to one another, on a divided circle, I soldered the ends to those of four other wires about ten feet long, these wires being connected with an elementary battery, composed of two parallel plates of zinc and copper, each containing four square inches. The plates were immersed in diluted acid and the degree of deflection observed. An elementary battery, composed of two parallel plates, each one inch square, and having a single copper wire of the same diameter and length soldered to each, was connected with the ends of the four short wires, the battery immersed in the same acid, and the deflections observed. The tangents of these deflections, reckoning from the middle of the wires, were very nearly in the ratio of one to two, whereas the quantities of electricity were very nearly as one to four. When my torsion galvanometer (which is founded on no assumption,) was employed, the degrees of torsion were found to be nearly as one to four.

Since the tangents of deflections do not afford us accurate measures of the deflecting forces, it is obvious that any law deduced from this method must be fallacious. The mode employed by M. Becquerel in determining the law of conduction was the following. Two wires of different diameters being placed parallel to each other, had electricity in opposite directions induced on, and the length of one of the wires shortened till the needle remained stationary and parallel to the conductors. Instead of using a thick wire, the section of which was double that of the other, he employed three wires of the same diameter, and found that two of the wires having the same length, and conducting electricity in the same direction, neutralized the effect of one wire having half the length, and conducting electricity in the opposite direction. From this he concluded that the conducting powers were directly as the area of the conducting section, and inversely as the length. It is somewhat remarkable that the fallacy of this conclusion has never been observed, or at least pointed out.

He might as well have concluded that the conducting power was directly as the square root of the area of the section, and inversely as the square root of the length, or, in short, as the nth root of the area of the section, and inversely as the nth root of the length. The fact is, M. Becquerel has deduced the values of two unknown quantities from one equation.

Having shown that the laws of conduction, which we have examined, have been deduced either by false processes of reasoning or by employing galvanometers founded on false principles, these laws must be equally fallacious.

Let us examine the law, if any such exists, which connects the conducting powers of wires with the lengths when the diameters are the same. If two wires of the same diameter, but of unequal lengths, (for example, the one being four times the length of the other,) be connected with a single pair of zinc and copper plates of the same size, and immersed in diluted acid of the same strength, the short wire may be found by my torsion galvanometer to have twice the deflecting force of the other. The conducting powers of the wires might, from this experiment, seem to be inversely as the square root of the length. If the strength of the acid be increased, the ratio of the deflecting forces will have changed, the long wire having now more than half the deflecting force of the shorter one. If, on the contrary, the strength of the acid or the size of the battery be diminished, the ratio of the deflecting forces will also have changed in favour of the short wire. Again, if the diameter of the wires be altered, the lengths being the same, the ratio of the deflecting forces will also vary with the size and energy of the battery employed. This is indeed what we might expect, without experiment. The conducting power of a wire must be a function of all the quantities concerned in the experiment. These quantities are obviously the diameter of the wire, its length, the size of the battery, and the strength of the acid. It is not, therefore, to be wondered at, that those who have attempted to ascertain the law of conduction, have failed in their attempts, since all of them have overlooked one of the essential quantities concerned in the investigation, viz. the size and energy of the battery.

These deductions are in perfect accordance with the views of conduction which I have already published in the Transactions of the Royal Society. Let us suppose that there is no actual transfer of electricity along the wire, but that all the phenomena of deflection, &c., result from a definite arrangement of the

electric fluid essentially belonging to the wire itself. Let us further suppose that a section of wire contains one hundred particles of electricity, and that the battery is capable of arranging one fourth of these, or twenty-five particles, then there will only remain seventy-five to be arranged by any increase of power. Let us now suppose we have another wire of the same length, whose section contains only twenty-five atoms; it is obvious that this battery will be able to arrange more than one fourth of this number, so that the ratio of the conducting powers cannot be as one to four, but will be found by actual experiment a very different ratio. If we increase the size of the battery, suppose the size of the plates to be doubled, then it is obvious we shall not double the deflecting power. For out of one hundred particles there are only seventy-five remaining, a part of which only can be arranged by the increased part of the battery. Hence the deflecting force increases very slowly with the increased size or energy of the battery.

We may conceive one of the conducting wires so diminished that the battery has arranged almost the whole of its electricity, in which case any increase in the size of the battery would scarcely produce any increase of deflecting force in the conductor. If these views be correct, it will obviously be in vain to look for a simple law of conduction involving only the lengths and diameters of the wires.

PART II.

ON CERTAIN PECULIAR PROPERTIES OF ELECTRO-MAGNETS.

Though the astonishing lifting powers of electro-magnets be sufficiently known, yet no attempt seems to have been made to investigate the law, if such exists, which connects this power with the length of the magnetic circuit. The subject appearing to me worth investigating, I procured two soft iron horse-shoe magnets (Plate VII. fig. 1.), with a short lifter, L, and having rolled the same quantity of covered wire about each, I had obviously the same inducing power when the ends were connected with the poles of the same battery. The lifter being suspended from the shorter end of a beam of light wood, and brought down on the poles of the magnet, the force by which the lifter was held could easily be ascertained by means of a sliding weight on the longer arm. The magnets, A and B, and lifter, L, were made from the same bar; the complete metallic

Fig. 1.

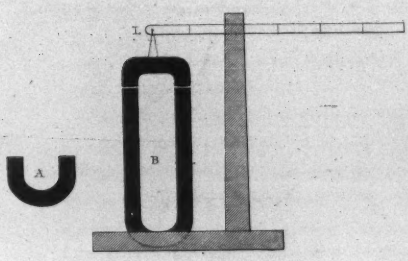


Fig. 2.

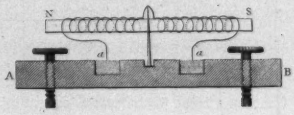
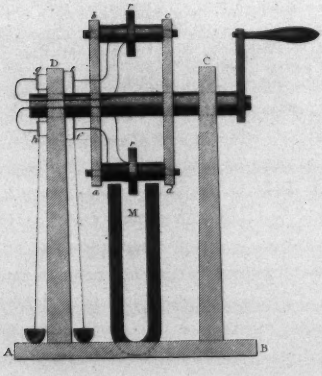


Fig. 3.



circuit in A being one foot, whilst that in B was four feet. By placing these magnets successively below the lifter, and connecting them with the poles of the same battery, the attraction of the short one was very nearly double that of the long one. This result seemed to lead to the conclusion that the lifting powers were inversely as the square roots of the length, which appeared to connect, in a remarkable degree, magnetic induction with voltaic conduction. Having discovered the fallacy of the generally received law of conduction, I began to suspect that no such simple law would be found to connect the lifting powers with the lengths.

Having substituted a more powerful battery, this simple ratio was immediately altered in favour of the long magnet, so that it now attracted the lifter with more than half the force of the smaller one: by diminishing the power of the battery, the ratio increased in favour of the short one. The reason of this variable law is obvious. When the battery is very powerful, it may be nearly able to arrange all the particles of electricity belonging to the soft iron, so as to give the short magnet nearly its greatest power. Any increase, therefore, in the size of the battery will produce very little increase of power in the short one, whilst the long one, not having more than half the power it is capable of receiving, will receive a considerable increase with every increase in the size or energy of the battery.

As a long magnet requires a large quantity of wire to cover it, and as the conducting power diminishes rapidly with the length, it is obvious the increase of lifting power which we gain by increasing the length of the magnet goes on very slowly, and that we must soon reach a limit beyond which no increase of power could be given. The truth of this observation will be rendered striking by the following experiment.

Having constructed, with great pains, an electro-magnet according to the American method, and connected it with a battery, I found it would carry about one hundred and forty pounds. I then rolled about twelve feet of copper ribbon about the middle of the lifter, which weighed about half a pound, and connected the ends of the coil with the same battery, the electro-magnet being now used as the lifter, and was surprised to find that the lifter was a more powerful magnet than that which had cost me so much labour to pre-

pare. All that is necessary, then, in making a powerful electro-magnet, is simply to roll a ribbon of copper (metallic contact being prevented by a thin tape interposed) about a short bar of soft iron, and use a short-shoe lifter.

In constructing an electro-magnet, it is necessary to attend particularly to the quality of the iron. I have tried experiments with various kinds of iron, from the best mitre to the worst English iron, and have observed that the worst iron I could procure is best adapted for making an electro-magnet. When a piece of fine iron is broken, it appears fibrous like a piece of wood. When the worst English iron is broken, it appears of a crystalline texture, exceedingly porous, resembling cast iron. This structure appears peculiarly adapted to allow the particles of the electric fluid to arrange themselves round the crystalline particles in that mode which constitutes a magnet.

It is easy to ascertain, before making an electro-magnet, whether a certain kind of iron be well adapted for the purpose. All that is necessary, is to forge a small lifter, and try it with a common horse-shoe magnet. If it be powerfully attracted by the magnet, it is good for the purpose; if not, it should be rejected. Having made two lifters, one of them of the best iron I could procure and the other of the worst, I found that a horse-shoe magnet with the first would carry only fourteen pounds; with the second it carried no less than twenty-seven pounds.

These facts will enable us to obtain the most powerful electric state by the induction of magnets. A lifter made of the iron I have described will give a much larger spark than one made of good iron. Another circumstance to be attended to in obtaining a large spark, is to use a short lifter, with a magnet having its poles near one another. When the lifter is short, the recomposition of the electric fluid, on the return of the particles to their natural state, is almost instantaneous, and consequently induces, for an instant of time, a more powerful electric state on the coil surrounding it. When the deflection of the needle is the object, a longer lifter may be employed with advantage.

That the recomposition of the electric fluid goes on more slowly in a long than in a short magnet may be shown by the following experiment. Take a long horse-shoe magnet of soft iron and convert it into an electro-magnet. Change the poles of the battery, and the lifter will fall off by its own weight. With a

short magnet the lifter will not fall off when the poles are rapidly changed; or if it does fall a little, it will be again attracted so rapidly as to bring it back to its former position.

In repeating these experiments, I was struck with a curious property of a long electro-magnet which had not been previously observed. When the wires were connected with the battery, and allowed to remain for a few seconds, and then removed, the lifter being disengaged, the soft iron scarcely retained any magnetic power. When the wires were again connected with the battery, it was rapidly converted into a magnet of considerable power. Having again removed it, and found the magnetic power almost destroyed, I connected the wires with the opposite poles of the battery, and was surprised to find that it required a long time to convert it into a magnet of much inferior power.

But the most beautiful result I have obtained from changing the poles of an electro-magnet, is the rapid rotation of such a magnet about its centre. The following short description of the first actually constructed will be sufficient to show how others of greater power may easily be formed.

Let A B, fig. 2., be a section of a circular sole of wood, having a circular groove, *a a*, turned in it for the purpose of holding mercury. The groove is divided into two compartments by thin slips of wood. These divisions are to be connected with the poles of the battery by means of cups, or in any other convenient way. N S is a piece of soft iron, having a copper wire rolled round it, the ends of the wires being made to touch the mercury in the two divisions of the groove. The electro-magnet is made to turn easily on a vertical axis, or on a fine point. The ends of the wire are adjusted so as to clear the two small divisions of wood, the surface of the mercury rising a very little above the divisions. If a horse-shoe magnet, having a considerable distance between its poles, be placed above the temporary magnet, the poles of the permanent magnet being directly above the slip of wood which divides the groove into two compartments, whilst the soft iron is converted into a magnet by means of the battery, a powerful and rapid rotation of the electro-magnet will take place; for the electro-magnet, being put in motion by the attraction of the poles of the other, will have its poles reversed the moment the wires pass the two divisions. At that moment attraction will be changed into repulsion, and the momentum thus acquired will be sufficient to carry the electro-magnet to that point where the

poles will be again changed, and consequently attraction will now take place. A single magnet, with one of its poles opposite the point where the change of poles takes place, is quite sufficient to continue the rotation. By a slight modification of the apparatus, horse-shoe magnets may be made to revolve with considerable force. I have fitted a revolving apparatus of this kind, which has a power sufficient to raise several ounces over a pulley. When the apparatus is placed so that the change of poles of the electro-magnet may take place in the magnetic meridian, the action of the earth is sufficient to make the magnet revolve without the aid of exterior magnets. By fitting it up so as to revolve in the plane of the magnetic meridian, and to change its poles at the point to which the needle dips, a dipping needle might be made to revolve in a vertical plane.

PART III.

ON A MODE OF OBTAINING AN ALMOST CONTINUOUS CURRENT OF ELECTRICITY BY THE INDUCTION OF MAGNETS.

After the nature of magneto-electric induction had been developed in the splendid and ingenious researches of Mr. FARADAY, and the mode of obtaining a spark from a common magnet by the method of SS. NOBILI and ANTINORI pointed out, I clearly perceived the mode of obtaining a current of electricity, *almost* continuous, by the revolving apparatus which I am now to describe. Though the apparatus was partly constructed nine months ago, yet the laborious duties of my profession prevented me completing it till very lately. The following is a description of the best form of the instrument for answering the various purposes to which it may be applied.

In fig. 3, A B is a sole of wood, with two supports, B C, A D. Through the tops of the two supports, an axis passes, having two circular discs of wood, *a b*, *c d*, fixed on it for the purpose of holding four cylinders of soft iron, of which two of them, *b c*, *a d*, are seen in the section of the instrument. These cylinders have ribbons of copper, *r r'*, similar to those used in my apparatus for exploding the gases by the magneto-electric spark. Wires, proceeding from the corresponding ends of these ribbons, are made to press against a circular plate of copper, *e f*, well amalgamated. The other ends are made to pass through the axis, and being bent as represented in the figure, are made to

press on a circular rim of copper, *g h*. This arc may be nearly a quadrant. The circular plate of copper and this rim have each strong copper wires soldered to them, and terminating in two cups for holding mercury. A horse-shoe magnet, either permanent or electric, is placed perpendicularly on the sole, so that each of the cylinders, when made to revolve by turning the handle, may pass very near the poles of the magnet.

If the handle be now turned rapidly round, each cylinder, in passing the poles of the magnet, will become a temporary magnet, and in doing so will induce an electric state on the ribbon of copper, the two cups being connected either with a galvanometer or in any other way. After passing the poles, it returns rapidly to its neutral state, and in doing so would induce an opposite electric state on the coil if the wire did not leave the rim of copper at the proper time. When one of the wires is leaving the rim, another is just entering, so that whilst one current is ceasing to act, the other current is just beginning. We have thus a series of currents of a variable nature following each other in rapid succession, and all acting in the same direction. This current will keep the needle of a galvanometer almost steadily deflected, and will make a wire revolve about a magnet as in Mr. FARADAY's first experiment. By increasing the size of the apparatus, all the other rotations might of course be produced.

If a circular piece of copper be fixed on one of the supports on the outside of the rim formerly described, and having its circumference cut into teeth like a saw, and if the ends of the wires be made to revolve on these teeth, this plate, and that on which the other ends of the wires revolve, being connected, a series of magneto-electric sparks will follow each other, in rapid succession, for very nearly a fourth part of the circumference. If four magnets be placed opposite the four cylinders of soft iron, almost the whole circumference may be illuminated at the same instant, producing a very beautiful effect.

XVI. *On the Anatomical and Optical Structure of the crystalline Lenses of Animals, particularly that of the Cod. By Sir* David Brewster, *LL.D. F.R.S. V.P.R.S. Ed.*

Received March 21,—Read May 9, 1833.

HAVING observed very singular phenomena in the crystalline lenses of fishes and quadrupeds when exposed to polarized light, I was led to examine their anatomical structure, with the view of ascertaining if it had any relation to these optical appearances. Leeuwenhoek and Sattig had previously made some progress in this research, but their methods of observation were ill fitted for so delicate an inquiry, and experience soon convinced me that the structure of the lens could not be thoroughly investigated either by the microscope or the scalpel.

Anatomists had long regarded the crystalline lens as composed of concentric laminæ, and these laminæ of minute fibres; but M. Soemmerring, in his work on the Human Eye, published in 1804, regards this structure as the effect merely of maceration in alcohol, and maintains that it does not exist in the recent or the living eye*. This decision, which its author has supported by many plausible but unphilosophical and inefficient arguments, appeared to set aside all the results which had been obtained by preceding inquirers, and rendered it necessary for me to adopt a new mode of investigation, which should not be liable to the same criticism.

The crystalline lens of the cod, like almost all globular lenses, has the form of a prolate spheroid, the axis of revolution being a little longer than the equatorial diameter. This axis is the axis of the eye, or of vision.

The body or substance of the lens is inclosed in an exceedingly thin and transparent membrane, called its capsule; and this membrane is so elastic

* Lens, post mortem ita tractata, etiamsi in segmenta sphærica, laminas et fibras dehiscat, tamen minime inde sequitur, lentem recentem seu vivam ex ejusmodi fibris, lamellis et segmentis sphæricis conflari, aut per vitam lentis sanæ fabricam zeolitidi ullo modo similem esse.—pp. 67, 68.

that when it was stretched upon a plate of glass, the extended portion polarized a blueish white tint of the first order. If we puncture the capsule, a thickish fluid flows from the opening; but upon removing the capsule altogether, this fluid is found to constitute only the outer coat of the lens, the substance of the lens growing denser and harder as we approach to the centre of it.

The body of the lens is not connected with the capsule, as Dr. YOUNG supposed, by any nerves or filaments whatever: on the contrary, it floats as it were within the capsule; and in holding the lens in my hand, I observed its axis of revolution take a horizontal position whenever it was placed in an inclined direction. This observation I repeated many times with the same lens, though I have not been able to do it with others.

When the lens is taken out of its capsule, and the softer parts removed by rubbing it between the finger and the thumb, we obtain a hard nucleus, the structure of which we shall now proceed to examine. In order to get rid of SOEMMERRING'S objections, I have often removed the recent lens from a newly caught fish, and taken out the nucleus without exposing it to any process of maceration or induration. I then detach a film or two from the nucleus, and find it to consist of regular transparent laminæ of uniform thickness, and capable of being separated like those of sulphate of lime or mica. The surface of these laminæ is perfectly smooth, and reflects light as copiously as any other polished substance of the same refractive power.

When we look with a microscope at the surface of any lamina, before it has been detached, it has the appearance of a grooved surface, like mother-of-pearl, or one of Mr. BARTON'S iris surfaces; and in large lenses it is often easy to trace these apparent grooves or lines to the two poles of the axis of revolution, the lines being widest at the equator, and growing narrower and narrower as they approach the poles. In small lenses, however, it is extremely difficult, and often impossible, to follow these lines to their points of convergency by the use of the microscope; and hence both LEEUWENHOEK and SATTIG maintained, that in fishes the points of convergency formed a line at each pole, the line at the one pole being perpendicular to the line at the other. These lines are bisected by the polar point, and the parts of the line on each side of the pole are called septa. Hence the lines or fibres which compose the laminæ are related to two septa in fishes, according to LEEUWENHOEK and SATTIG.

Fig. 1.

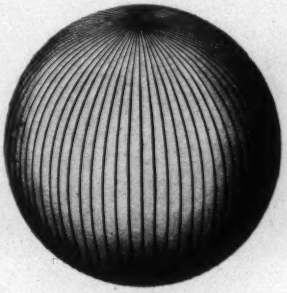
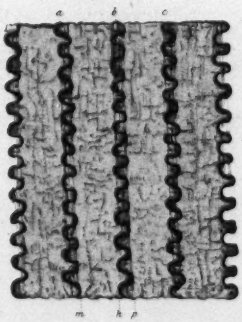


Fig. 2.



In examining these phenomena, I observed the surface of the laminæ sparkling with the colours of mother-of-pearl*, and upon applying a microscope, adjusted to such a focus as to show distinctly the reflected image of the candle, I observed on each side of this image one or more highly prismatic images, produced by interference, like those of grooved surfaces. As the direction of the fibres is necessarily perpendicular to the line joining the coloured images, I was enabled to trace them to their termination, or points of convergency, when the fibres themselves could not be rendered visible by the best microscope. But while this new method of observation enabled me to detect all or most of the varieties of fibrous organization which exist in the crystalline lenses of animals, it furnished at the same time a simple and accurate method of determining the diameter of the fibres at any point of the spheroid. The distance of any of the coloured images from the colourless image was a direct measure of the breadth of the fibres; and with the aid of a series of Mr. Barton's beautiful divisions upon steel, from 312·5 in an inch to 10,000, which he was so kind as to make for me, it was easy to obtain these measures without even the trouble of calculation.

By these means I succeeded in tracing the fibres, or thin slender laminæ, to two poles diametrically opposite to each other, and coinciding with the poles of the spheroidal lens, as shown in Plate VIII. fig. 1. In small lenses, and particularly in the lenses of birds, the accurate convergency of the fibres to one focus is less distinctly seen; but it is easy to distinguish this diffused polarity, as it may be called, from the convergency of the fibres to points arranged in a straight line, and constituting the two septa already mentioned.

The distribution of the fibres now described is the simplest that occurs in the lenses of animals. Every fibre has the same length and the same form; and its curvature is, like the meridian of a spheroid, without any contrary flexure.

The perfect flatness of the surfaces of the concentric laminæ, as indicated by their power of forming a distinct image by reflexion, shows that the fibres which compose them are flat and not cylindrical; and when we look through them with a powerful microscope, this conclusion is amply confirmed by the uniform distribution of the refracted light.

* These colours may be transferred to wax, &c., like those of mother-of-pearl.

In order to measure the diameter, or rather the breadth of the fibres, I detach from the equator of the lens an extremely thin lamina, and having placed it above a small aperture in a plate of brass, I look through it at a candle, and measure the angular distance of the first coloured image from the white or central image, taking the centre of the red ray as the point from which the measurement is to be taken. When the first coloured images on each side of the central image are extremely distinct, it will be better to measure the angular distance of the red parts of their spectra, and to take half that distance as the angular distance of the first image from the central image. If we call this distance A, and put B for the breadth of each fibre, or the breadth of the transparent part, together with the breadth of the opake interval or line which separates the fibres, we shall then have $B = \frac{C}{A}$, C being a constant quantity for the red ray to be determined by experiment. According to FRAUNHOFER's experiments on Interference, C is equal to 0·0000256 of an English inch for the middle red ray; hence the formula becomes $B = \frac{0{\cdot}0000256}{A}$.*

In order, however, to save the trouble of calculation, and in cases where a general estimate only is required, I use Mr. BARTON's system of grooves already mentioned; and upon looking through the lamina at the white image, or rather the central image of the iris surface, I can at once compare the distance of the first prismatic images of the one with the same distance in the other. If I am using, for example, the divisions of 5000 in an inch, and if I find the distances of the coloured images the same with the laminæ and with the steel, I infer that the breadth B is the 5000dth of an inch. This conclusion, however, is not quite correct, for we may have been comparing the effect of a perpendicular incidence on the lamina with the effect of an oblique incidence on the steel. Now, FRAUNHOFER has shown that the coloured images separate as the incidence in a plane intersecting the grooves at right angles is increased, and that the value of B, to which this increased distance corresponds, is smaller in the proportion of radius to the cosine of the angle of incidence, I. Hence the formula becomes $B = \frac{0{\cdot}0000256}{A \cdot \cos . I.}$. This property gives us the advantage of

* FRAUNHOFER found that in a system of lines where B was 0·0001223 of a Paris inch, A was 11° 25′ 20″; and in another system, where B was 0·0005919, A was 2° 20′ 57″.

a variable scale; and in making the experiment, I found that at an incidence of 25°, when the divisions of 5000 in an inch were employed, the coloured images of the laminæ corresponded with those of the grooved steel. Hence the value of the quantity B, or the breadth of the fibres, is about the 5500dth part of an inch.

I next detached laminæ from parts nearer the pole, and I found that the coloured images gradually separated as the fibres approached to the poles; thus proving, what might have been inferred from other facts, that the fibres gradually taper in breadth from the equator to the poles of the lens. In order to allow the fibres to be packed without condensation into spherical laminæ, their breadths must diminish as the cosine of the distance from the equator.

Although the prolate form of the spheroid indicates that the thickness of the laminæ, or of their component fibres, must increase slightly towards the poles, yet I have not been able to prove this experimentally, or even to determine the thickness of the fibres. I have more than once detached, by accident, a single fibre from the mass, and by an examination of the black line which forms its edges, I am satisfied that its thickness is at least five times less than its maximum breadth.

Having thus determined the form and size of the fibres, we come now to a very delicate and interesting part of the inquiry, namely, to ascertain the mode in which the fibres are laterally united to each other, so as to resist separation, and form a continuous spherical surface. The remarkable mechanism by which this is effected was first pointed out to me by an optical phenomenon. In looking at a bright light through a thin lamina of the lens of a cod, I observed two faint and broad prismatic images, situated in a line exactly perpendicular to that which joined the common coloured images. Their angular distance from the central image was nearly five times greater than that of the first ordinary prismatic images, and no doubt whatever could be entertained that they were owing to a number of minute lines perpendicular to the direction of the fibres, and whose distance did not exceed the $\frac{1}{2500} \times 5$, or the 12,500dth of an inch.

Upon applying a good microscope to a well-prepared lamina, I was delighted to observe the structure shown in fig. 2, where the two fibres, *a b*, *b c*, are united

by a series of teeth, exactly like those of rackwork, the projecting teeth of one fibre entering into the hollows between the teeth of the adjacent one. The length of the teeth, or np, is equal to about one half of mn, and this length of course diminishes towards the pole in the same ratio with the fibre. The breadth of the teeth is such, that five of them, namely, three of one fibre together with the two teeth of the adjacent fibre, which they inclose, are equal nearly to $mn + np$, which is the measure of the quantity B in the preceding formulæ. With an ordinary microscope, the series of teeth between any two fibres seem to form a dark line, whose breadth is np; and it is in consequence of the interruption of the light thus occasioned, when the lamina is dry, and the surfaces not in optical contact, that the fibrous lamina acts upon light like grooved steel, the space np in the lamina corresponding to the groove formed by the cutting diamond point in the metallic surface.

Although the parallel sides of the teeth do not form continuous lines, yet they produce colours by interference in the same manner as if they were continuous; and it is by their influence that the secondary prismatic images are produced in a line perpendicular to the sides of the teeth. In the living as well as in the recent lens the faces of the teeth and of the fibres are all in optical contact, and light passes through them in every direction in the same manner as if the whole lens were a continuous solid.

The toothed structure which has now been described, I have found in the salmon, haddock, herring, shark, and, indeed, in the lens of every fish where I have looked for it; and in this class of animals it is generally very distinct, and almost always capable of producing the secondary prismatic images. In the salmon, however, the teeth are much narrower than in the cod, and the colours which they produce are less distinctly seen.

Having thus determined the form and magnitude of the fibres and their teeth in a given lamina, it becomes interesting to ascertain if they suffer any change in shape or size at different distances from the centre of the lens. With this view I continued to remove one coat of the lens after another, till I reduced it to such a minute nucleus that I could no longer use it. I then dried it at the fire, and having crushed it, I obtained small portions of laminæ extremely near the centre: in this way I found that the fibres gradually diminished towards the centre of the lens, and the teeth in the same proportion, so

that the number of fibres in any spherical coat or lamina was the same from whatever part of the lens it was detached.

In the lens of a cod, I found that there were 2000 fibres in an inch at the equator of a spherical coat or lamina, whose radius was $\frac{1}{10}$ths of an inch; consequently there must have been 2500 in the spherical surface*. If we now suppose that the breadth of each fibre is five times its thickness, and that each tooth is equal to the thickness of the fibre, or that five teeth are equal in breadth to a fibre, we shall obtain the following results for the lens of a cod four tenths of an inch in diameter:

Number of fibres in each lamina or spherical coat	2,500
——— teeth in each fibre	12,500
——— in each spherical coat	31,250,000
——— fibres in the lens	5,000,000
——— teeth in the lens	62,500,000,000

or, to express the result in words, the lens of a small cod contains five millions of fibres, and sixty-two thousand five hundred millions of teeth. A transparent lens exhibiting such a specimen of mechanism may well excite our astonishment and admiration!

The magnitude of the fibres and of their teeth varies in different animals. In the lens of a South American fish, for example, called the sheep-head, there are only 613 fibres in a spherical surface†; but it will be seen in a subsequent Paper, that there are other animals in which the fibres are still more minute than those in the lens of the cod.

By means of very fine microscopes, with high magnifying powers, I have succeeded in detecting the same structure in the lenses of birds and quadrupeds; but in these classes of animals it is much less distinctly developed than in fishes. The teeth are much shorter; and when the lens belonged to an aged animal, the toothed structure was extremely indistinct and irregular, and in some parts of the fibres it entirely disappeared.

The fibrous structure represented in fig. 1, and in which the fibres converge to two opposite poles, is never found, in so far as my observations extend, in any

* The radius being $\frac{2}{10}$ or ·2, we have $3{\cdot}1416 \times {\cdot}4 \times 2000 = 2513$.

† The diameter of the lens was $\frac{4}{10}$th of an inch, and there were 975 fibres in an inch at the equator.

of the Mammalia or Cetacea. It is the universal structure in the lenses of all the birds that I have examined; and though it is the most common structure in fishes, it is not the only one which they exhibit. In the following Table, I have given the names of the different animals in whose lenses I have found the structure shown in fig. 1.

FISHES.

Cod.	Spirling.	Eel.
Haddock.	Loch-leven Trout.	Pike.
Serpent Fish.	Turbot.	Mackerel.
Diver.	Sole.	Coal Fish.
Mullet.	Sayd.	Gold Fish.
Herring.	Grey Dog.	Great Lamprey.
Holibut.	Flying Fish.	Bull-head.
Fresh-water Fluke.	Frog Fish.	Whiting, English.
Salt-water Fluke.	Sea Cat.	

BIRDS.

Cassowary.	Magpie.	Pheasant.
Albatross.	Plover.	Penguin.
Pelican.	Common Pigeon.	Cock.
Crane.	Wood Pigeon.	Hen.
Turkey.	Emberiza.	Green Linnet.
Barnacle Goose.	Alauda arvensis.	Ornithorhynchus.
Sea Eagle.	Tringa.	
Snowy Owl.	Black Grous.	LIZARDS.
Curlew.	Red Grous.	Lacerta striata.
Chaffinch.	Partridge.	Lacerta Calotes.
Thrush.	Wild Duck.	

For many of the lenses in the preceding Table, and for others which I shall have occasion to enumerate in subsequent communications, I have been indebted to the kindness and zeal of Captain BASIL HALL, Captain ROBERTSON, Professor GRANT, Mr. GEORGE SWINTON, Dr. KNOX, Mr. WILLIAM CLARK, and Mrs. GREEN of Cumberland Island.

In the Philosophical Transactions for 1816, I have described and represented

by drawings the singular structure of the crystalline lens of the cod, as exhibited by transmitting through it a beam of polarized light. I have there shown that it consists of three different structures; viz. the nucleus, which has negative double refraction like calcareous spar; the external strata, which have the same kind of double refraction; and the intermediate strata, which have positive double refraction like zircon. The axis of vision, or that of the spheroidal lens, is the axis of double refraction for these three structures. I have discovered the same structure in the lens of the haddock, the salmon, the frog fish, the skate, and the whiting, and indeed, with more or less distinctness, in all the lenses of fishes which were large enough to show the polarized tints.

A doubly refracting structure, related to the axis of vision, is distinctly seen in the human lens, and in that of quadrupeds and birds; but it differs considerably, both in its character and intensity, from that which exists in the lenses of fishes. In the paper to which I have already referred*, I have stated that in the lenses of sheep and oxen there is only one series of luminous sectors, or one structure, corresponding with the intermediate set in the crystalline of fishes. This, however, is a mistake. By nicer means of observation I can distinctly see all the three structures in the lens of the sheep, the ox, and the horse; but, what is very singular, the nucleus and outer structure have positive double refraction, while the double refraction of the intermediate structure is negative; a result exactly the reverse of that which I have obtained from the lenses of fishes. If this triple structure is intended, as I have already conjectured, to correct aberration, or to improve vision, it will be a curious problem to determine how this is effected, and to connect the one structure with the existence of a spheroidal lens without the aqueous humour, and the other with the co-existence of a flat lens and an aqueous humour.

When the lens of a cod is prepared so as to indurate and retain its form and transparency, the process of induration confounds all the three structures in one; viz. a negative doubly refracting structure many times more intense than that which exists in the recent lens. When a lens thus indurated was exposed to polarized light, I observed round the axis of the lens a beautiful system of negative uniaxal rings, seven in number, and intersected with a well-defined black cross. When the polarized light passed through any equatorial diameter

* Philosophical Transactions, 1816, p. 315.

of the lens, a system of seven biaxal rings was beautifully displayed, the principal axis being of course negative. This system of rings was intersected by the black cross, when the plane of the equator coincided with that of primitive polarization, and they displayed the two dark hyperbolic branches when the inclination of these planes was 45°. These phenomena I observed most distinctly in the lens of the boneta; and I have seen them also in the lenses of the cod, the shark, and the flying fish, which happened to have been preserved without any fissures or loss of transparency.

In looking at a candle through the indurated lens of a cod, held at a distance from the eye, and which had been preserved for three years, I observed the candle encircled with three beautiful concentric rings, red on the inside and green without. These colours were no doubt those of mixed plates.

In examining the laminæ of the crystalline lens under the microscope, we are often perplexed with a variety of colours apparently spread over the surface of the plate. These colours are not the effect of chromatic aberration, but arise from the interference of the coloured pencils produced by the two surfaces of the laminæ. If we take a thin lamina, and, holding it opposite to a candle, look at its surface with a lens about an inch in focus, we shall see the whole of it covered with the most brilliant and varied colours, not inferior to those of the richest opal. These colours vary as we incline the laminæ in a plane cutting the fibres of it perpendicularly; and when the portion of the lamina is flat, they form a series of rectilineal serrated fringes perpendicular to the direction of the fibres. When the portion of the lamina is much curved, the fringes are irregular, and form, occasionally, returning curves of every variety of form and of every imaginable tint. If we immerse one of the surfaces of the lamina in a fluid of the same refractive power, we remove, as it were, the fibrous structure of that surface, and the serrated fringes immediately disappear. This observation led me to imitate these fringes by combining two series of grooves cut on the surface of separate strips of glass*. The effects were precisely similar and highly beautiful; and in the prosecution of the subject I was led to the observation of a series of very curious phenomena, which will form the subject of a separate communication.

* These phenomena are much more splendid, when the grooves are formed upon thin plates of isinglass, by taking an impression of them from a steel surface.

XVII. *On the magnetic powers of Soft Iron.* *By Mr.* Francis Watkins. *Communicated by* J. G. Children, *Esq. Sec. R.S.*

Received April 16,—Read April 25, 1833.

1. A STRAIGHT bar of soft iron, when placed in the vicinity of the poles of a real or artificial magnet, acquires the properties of a magnet; but this power conferred by induction is of a temporary nature, for we find that when the soft iron is withdrawn all its magnetic effects cease.

2. None of those processes which are employed to form permanent steel magnets, will induce a magnetic state on a straight soft iron bar capable of being retained by the bar.

3. When an electric current traverses a copper conducting wire coiled around a piece of soft iron, a powerful temporary magnet is obtained; but when the flow of the electric current ceases, the magnetism developed by the soft iron ceases also.

4. These I believe to be the notions of most persons having a knowledge of magnetism. According to these notions, soft iron can only exhibit magnetic powers when immediately under the influence of induction; consequently soft iron has little or no retentive power within itself, that faculty belonging exclusively to hardened steel.

5. I have, however, noticed that soft iron, under certain conditions, not only possesses the power of retaining magnetism, but that this power does not appear to be weakened by time.

6. Although the fact itself, abstractedly considered, may not be thought of much consequence, yet, perhaps, viewed in conjunction with many others on the same subject already before the world, and with other facts probably still to be revealed, it may be of use in a future classification of magnetic phenomena.

7. The experiments were principally made with four pieces of soft round bar iron, eighteen inches long, and one inch in diameter; each bent into the form of a horse-shoe, and furnished with a keeper of soft iron. About twenty

feet of copper wire, one-fifteenth of an inch thick, was wound around each of the soft iron horse-shoes in a single helix. Compound helices would certainly have made the horse-shoes more magnetic; but as the object was simply to try whether the magnetic principle were permanent, I was content to obtain a certain force, and endeavour to discover whether the intensity of that force remained undiminished after a lapse of time; which I found to be really the case.

8. One of the soft iron horse-shoes, above described (7.), was submitted to the influence of an electric current, by the ends of the copper helix which encircled it being connected with the metallic elements of a voltaic battery of a single pair of plates. While the current traversed the helix, the soft iron supported one hundred and twenty-five pounds. Without breaking the connexion between the copper helix and the battery, the weights were reduced to fifty-six pounds, and then the battery was taken away altogether. The soft iron horse-shoe still supported firmly the fifty-six pounds. The weight was then removed, at the same time special care being taken not in the least to disturb the keeper. Every day the sustaining power of the soft iron horse-shoe was tested, and it was found that it would hold fifty-six pounds suspended by its keeper, just as firmly at the end of ten days as it did when tried in the first instance. The soft iron horse-shoe being required for other purposes, the keeper was violently removed after the last experiment; and then all the magnetism disappeared.

9. When a compass needle was made to approach towards the extreme ends of the branches or poles of the soft iron horse-shoe, while connected with its keeper, a polar state in the soft iron was distinctly marked by the respective attractions and repulsions of the ends of the needle, as they agreed or disagreed in polarity with those of the soft iron. In short, the attractions and repulsions were precisely like those which take place when a compass needle is placed within the sphere of influence of the poles of permanent horse-shoe magnets.

10. One of the soft iron horse-shoes (7.) was saturated with magnetism, by means of the electric current traversing the copper helix around it. The weight supported, while the current was present, amounted to seventy-eight pounds. Twenty-eight pounds were appended to its keeper, and the flow of electricity stopped; attention being paid (as in the first case,) that the union

between the keeper and the poles should in no degree be interfered with. In the absence of the voltaic battery, the soft iron still supported the twenty-eight pounds; and when tried day after day, for nearly a fortnight, was found, like its companion (8.), to be as powerful on the last day as on the first.

I notice this experiment, in order to show that, although one piece of soft iron may not be so susceptible of the magnetic virtue as another, still one of inferior power will retain its virtue like another whose power is superior; the absolute quantity of magnetism being the only difference between them.

11. At the suggestion of Mr. CHRISTIE, I had two pieces of soft round bar iron, one inch in diameter, bent into semicircles, so that when their filed flat ends were placed together, the two formed a circle of about six inches internal diameter. Each of the semicircular pieces of soft iron had a copper wire wound around it one-fifteenth of an inch in diameter and fifteen feet in length, in the order of a single helix. Each coil of the helices commenced and terminated as closely to the ends of the semicircles as could be effected with safety to their being retained there.

12. When a circle was formed by the two pieces of soft iron, and an electric current was passing along one of the helical systems of copper wire, a polar arrangement was instantly made manifest, by the action produced upon a suspended compass needle placed within the circle, the opposite magnetic states being observed nearly about the junction of the semicircles, as was anticipated, in consequence of the helix transmitting the electric current, commencing and terminating at those points. The suspended compass needle, in obeying the magnetic influence of the polarity of the circle, arranged itself with its poles opposite dissimilar poles in the circle; and this effect took place whatever situation the poles of the circle occupied as regarded the magnetic meridian.

13. While one half of the circle was rendered magnetic by the presence of an electric current in the helical coil which enveloped it, the other half was attached, and was powerfully attracted. Under these conditions, the flow of the electric stream was interrupted: the attraction still continued, and a weight of twenty-one pounds was upheld, on being hung to the lower half of the circular arrangement, and the magnetic power remained undiminished, so long as the semicircles were not separated.

14. The polar arrangement in the soft iron circle is apparently different while the electric current passes along the helix, enveloping one half, and after the electrical influence is withdrawn: in the first case, in spite of the intervention of a thin plate of mica between each junction of the semicircular pieces, so long as the electric current is present in either helix, the extremities of the semicircles, in approximation, develop *similar* polarities; in other language, the contiguous ends are either both north or both south poles; whereas, on interrupting the transmission of the electric current, the ends in approximation are found to be respectively in opposite states, being north opposed to south, and vice versâ. Similar phenomena are exhibited by electro-magnets of all shapes and sizes, provided the exciting current be very intense; but if it be feeble, the common law obtains whether the electric current be present, or whether it be absent. Of course it is here understood that no rupture has taken place.

15. Several weeks after one of the pieces of soft iron (7.) had been magnetized by the electric current, it was found to be equal in strength to what it was when first it acquired its magnetism. Its original keeper was gently slid off its poles; at the same time a new but similar kind of keeper was progressively slid on; the precaution, of course, being taken that the first keeper was not completely removed before the new keeper was well seated in its place. The soft iron was then tried as to its magnetic power, and it proved full as powerful after the change of keepers as it did before any alteration had been made. Many experiments have been made upon this branch of the subject, and the results found to be uniform in all cases.

16. A straight cylindrical rod of soft iron, ten inches long, and three quarters of an inch in diameter, had eight feet of copper wire wound around it one-fifteenth of an inch in diameter. While an electric current was passing along the copper wire, the rod of soft iron evinced magnetic powers, and kept suspended at its extremities or poles, pieces of soft iron. The ends of a piece of well-annealed iron wire were bent at right angles, so that they could attach themselves to the extremities of the cylindrical rod of soft iron, when it was made into a magnet by the agency of the electric current. On interrupting the electric circuit, it was observed that the arms of the bent wire still adhered to the poles of the cylindrical rod. When iron filings were presented to the

bent portions of the wire, they were attracted and adhered to them. A compass needle was next placed in the vicinity of both poles (successively) of the cylindrical rod, and it became affected in the same manner as when applied to a straight bar steel magnet. When the bent wire was disconnected from the cylindrical rod of soft iron, no appreciable magnetism could be discovered in either the wire or the rod.

17. One of the soft iron horse-shoes (7.) has been allowed to remain charged with magnetism since the middle of last November, and it is now as powerful, if not rather more so, as when first it received the magnetic virtue. Unfortunately, no record was taken at the time as to the precise weight it would uphold. It has, after a lapse of fifteen weeks, frequently supported thirty pounds; and from the force found necessary to slide its keeper through a small space along the surfaces of the poles, it is presumed that its powers are much beyond those here quoted; but being fearful of separating the keeper, the sustaining power of this soft iron magnet has not as yet been put to a severer test than thirty pounds*.

18. A piece of soft bar iron, nineteen inches long, and one inch square, was bent into the form of a horse-shoe, and magnetized by the same procedure as that followed in forming permanent steel magnets, called "touching or rubbing." The exciting magnet was a powerful electro-magnet, and after the square iron horse-shoe had been rubbed some few times backwards and forwards, and withdrawn carefully, to prevent any disturbance between its poles and keeper, it was observed that the square iron horse-shoe would sustain a weight of more than thirty pounds. This power resided in the piece of iron as long as the union between its poles and keeper was uninterrupted; when a rupture took place between them, all magnetism disappeared.

19. At another time, the above-mentioned piece of square bar iron was

* At a Soirée which I had the honour of attending at Kensington Palace on the 27th of April, it was tried, in the presence of H. R. H. the Duke of Sussex and many noblemen and gentlemen, what was the greatest weight the above-mentioned soft iron horse-shoe magnet could support; and it was found that although nearly six months had elapsed since it received the magnetic virtue, yet it was capable of upholding 100lbs.; but the moment the keeper was separated from the poles, almost all the magnetism disappeared. So trifling, indeed, was the residual magnetism in the soft iron horse-shoe, that when the keeper was again applied to the poles, there was not attractive force sufficient even to support the keeper.

rubbed with a steel permanent magnet, and it was found to be equally susceptible, and equally retentive of the magnetic virtue it received from the steel magnet, as it was with that impressed by the electro-magnet. When the keeper was disunited from the poles, magnetism was no longer apparent either in the square bar iron, or in its keeper.

Hence it is clear, that the magnetism conferred on soft iron, by the process of "touching or rubbing," is retained with the same energies as that impressed by electric currents.

20. Another method was adopted to illustrate the powers of soft iron to retain magnetism. One of the pieces of soft round bar iron, bent into the form of a horse-shoe (7.), was stripped of its single helix of copper wire, and in lieu thereof, had sixty feet wound around it in six separate helices, after the fashion recommended by the American philosophers. This soft iron horse-shoe was then fitted up with the necessary apparatus, to show the electric spark by magneto-electricity. It was found, that for days after the magnetism was conferred on the soft iron horse-shoe, when its keeper was suddenly disengaged from the poles, an electric spark was evolved. The spark was not so brilliant as it would have been had the rupture been made while the soft iron was directly under the influence of the electric current; but still the electric spark was displayed by magnetic agency, and it is well known that there must be a considerable concentration of magnetism to exhibit electrical light. This very interesting experiment has been repeated many times with perfect success. The mechanical arrangement of the apparatus necessary to show the electric spark is not here adverted to, because the evolution of electricity by magnetic agency is not the immediate object of the paper; but it may be cursorily noticed, that soft iron magnets are decidedly to be preferred for the exhibition of magneto-electric phenomena, and for showing the electrical light evolved by soft iron magnets: those made of the common English iron of commerce are the best.

21. A horse-shoe of soft iron, with a copper helix (7.), was magnetized by an electric current. Between the poles and the keeper a thin lamina of mica was interposed. While the current was present in the wire, the magnetic powers of the soft iron enabled it to support fifty-five pounds suspended to its keeper. The weights being removed, and the connexion between the voltaic

battery and the copper coil interrupted, the horse-shoe of soft iron retained sufficient magnetic power to support twenty pounds, in spite of the interference of the mica, between the poles and the keeper. The horse-shoe of soft iron was tried, day after day, for nearly two months, and the magnetic force it displayed seemed to be undiminished; so that it was here evident, the mica screen in no degree interfered with the retaining power of the soft iron, although it decidedly did in respect to the weight it would uphold.

22. To ascertain how far the screening effects of thin plates of mica might be extended, so as partially, if not wholly, to overcome the attractive force exerted between the poles of the soft iron magnet and its keeper, and thus destroy all sustaining power, the following experiments were made. On each separate experiment an additional plate of mica was added to that already interposed between the poles and the keeper, and the zinc element of the voltaic battery was well cleansed each time to secure, if possible, equal inducing effects from the electric current. One of the soft iron horse-shoes (7.) was employed, and while the electric current was being transmitted along the copper coil of wire which enveloped it, the horse-shoe supported, with one plate of mica placed between its poles and the keeper, forty-nine pounds; with two plates, forty pounds; three plates, twenty-six pounds; four plates, seventeen pounds; five plates, thirteen pounds; six plates, eight pounds; seven plates, four pounds and a half; eight plates, two pounds and a half; nine plates, two pounds; ten plates, one pound and a half; eleven plates, one pound; twelve plates, three quarters of a pound; thirteen plates, half a pound; fourteen plates, the keeper only; fifteen plates, nothing.

23. While the electric current was traversing the copper wire, coiled around one of the horse-shoes of round bar iron (7.), a piece of common writing-paper was placed between the poles and the keeper; still twenty-eight pounds were supported by the horse-shoe of soft iron. When the voltaic battery was removed without at all meddling with the keeper, and the magnetism of the horse-shoe tried, it was evident a sustaining power existed, for several pounds weight were upheld. Further, in successive trials, for days afterwards, the same power still remained; but when endeavouring to ascertain the exact weight the horse-shoe would support, the keeper broke from it, and the magnetism disappeared. Many experiments of this nature were made, and varied

as regarded the screening substances; but as the results accorded generally with those detailed in this and the preceding paragraph, it has not been considered worth while to particularize them.

24. The magnetism developed by soft iron, when immediately under the inductive influence of an electric current, is eminently useful in the formation of artificial magnets. The magnetism it confers on the steel is equal, if not superior, in intensity to that bestowed by a permanent steel magnet; and when it is remembered, that a soft iron magnet of immense power can be commanded at all times, through the aid of a small voltaic battery, it is clear that a soft iron magnet affords not only the most excellent but the most economical and ready source of magnetism that could be desired.

I have for some time been in the habit of employing soft iron magnets to magnetize both simple and compound hardened steel horse-shoe as well as straight bars; and by paying strict attention to the procedure proper on these occasions, I have been enabled to obtain magnetism in a high state of concentration, in the hardened steel which I submitted to the action of the soft iron magnet.

25. If the steel bar be round and small, no better method can be pursued for imparting the magnetic principle to it, than that of enveloping it in a copper wire helix, and passing a voltaic current through the helix. This procedure was suggested by M. Arago and Sir Humphry Davy, about the same time, in 1821.

26. When performing the experiments whence the preceding results were obtained, it very frequently happened that a separation was effected between the keeper and the poles of the soft iron, sometimes designedly, at others unintentionally; but it was observed in all cases, that separation, whether made immediately after the soft iron had been saturated with magnetism, or after it had retained its magnetism for weeks, still the greatest portion, indeed nearly the whole, of the magnetism of the soft iron was destroyed almost instantaneously; the soft iron retaining only as much as would enable it to support the keeper, and frequently not that, even when the keeper was immediately replaced after a rupture.

This slight retentive property of the soft iron for magnetism, after a rupture, I conceive not properly to belong to the iron itself, but to be caused by the

iron being mixed more or less with steel. The fact of iron retaining a trifling portion of magnetism has long been known to those engaged in the science of electro-magnetism, as also its capriciousness in developing magnetic energies. Among those who, I know, have particularly noticed these facts, I ought to mention my friends, Dr. Daubeny, Mr. Marsh, and Mr. Sturgeon.

27. When I first undertook to perform the series of experiments, the results of which have been briefly detailed, I had in view a different object from that I have since obtained; for I thought the soft iron with its keeper resembled in a manner a closed voltaic circuit. But subsequent observations have led me to conclude, that the whole phenomenon resolves itself simply into a novel case of complex induction. As thus, the horse-shoe of soft iron is made a strong magnet, by the inducing effects of the electric current transmitted along the helical coils of copper surrounding it. The keeper, being a bar of soft iron, is made a magnet by the inductive influence of the magnetism, active at the time in the soft iron horse-shoe, and becoming powerful by the poles of opposite denomination in the soft iron horse-shoe conspiring, equally, to induce opposite poles in the ends of the keeper. Consequently, the great sustaining power possessed by the soft iron horse-shoe (7.) and its keeper, is the result of combined efforts; or in other words, we have two magnets, placed end to end, with dissimilar poles in approximation; which position is well known to increase magnetic effects very considerably, and also to preserve the magnetism.

28. From what has been said and experimentally proved, it appears that when two pieces of soft iron, the extremities or poles of which are so disposed that the one pole of one piece has the power of inducing a dissimilar pole on the end opposite to it in the other piece, the magnetic effects are very considerable, and, what is very singular, are inclined to be permanent, that is, so long as the two pieces are very near to each other; and thus situated they resemble a hardened steel magnet with its keeper.

29. That induction, of a complex kind, is the cause of the phenomena noticed in this paper, there can be little doubt; for it is clear, by experiments 13. and 14., that an appreciable interval existed by the intervention of the mica and writing paper, so that nothing like a continuous flow of electricity or magnetism could have prevailed in the system formed by the soft iron horse-shoe and its keeper. Besides, it was observed in one case, that when the keeper of

one of the soft iron horse-shoes (7.), which, when connected, had occasionally supported twenty-eight pounds for many days after saturation, was disengaged, a coat of rust covered not only the flattened surfaces of the poles of the soft iron horse-shoe, but also the keeper. These surfaces were quite clean when the soft iron horse-shoe received its magnetism, and the rust was produced by its being hung accidentally (when charged,) over a place where a galvanic battery, in a high state of excitement, was perpetually brought into operation. Here again there was an interval, of some extent, between the smooth portion of the poles and the keeper; so that nothing like a continuous circuit could here have been established; and yet, in this condition, the soft iron horse-shoe and its keeper, by their reciprocal action, had the power of resisting a separating force equal to a weight of twenty-eight pounds.

30. I have frequently noticed, when experimenting with electro-magnets which would support from four to five hundred pounds weight, that when the keeper was slid backwards and forwards upon the flattened poles of the electro-magnets, only one or two faint streaks were visible, either upon the poles or the keeper; consequently, there could have been metallic contact only in the parts where those streaks were produced; and yet the surfaces were as perfect as they could be made by hand. Hence the sustaining power of the electro-magnet was dependent upon complex induction; in short, it appears evident, that all magnetic phenomena belonging to this class of effects have their origin in that influence termed induction, but which, when both magnetic states operate, is properly called complex induction.

5, *Charing Cross*,
March 16, 1833.

XVIII. *On Improvements in the Instruments and Methods employed in determining the direction and intensity of the Terrestrial Magnetic Force.* By S. Hunter Christie, *Esq. M.A. F.R.S. M.C.P.S. Soc. Philom. Paris. Corresp., &c.*

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ALL who have had occasion to make observations with a dipping needle, are aware of the tedious nature of those observations, and of the uncertainty which frequently attends the results, even when the best instruments that can be procured are employed. The observations by which the terrestrial magnetic intensity is determined are more tedious, and subject even to greater uncertainty. Having long been sensible of the imperfections of the instruments by which the dip is determined, the improvement of them has at different times engaged my attention; and various methods have suggested themselves by which, theoretically, this might be effected, but practical difficulties, at the same time, presented themselves to these proposed improvements.

The uncertainty attending dip observations arises principally from two sources; the want of perfect freedom of motion on the axis, and the non-coincidence of the centre of gravity of the needle with the axis of motion, the latter rendering necessary the inversion of the poles of the needle. It is now many years since it occurred to me, that increased freedom of motion might be obtained by making the axis of the needle a very acute double cone, instead of a cylinder, and inclining the agate planes at a greater angle to the horizon than half the angle of each cone: but it appeared to me also, that a degree of horizontal pressure on the axis would arise from the inclination of the supporting planes, which might counterbalance the advantages arising from the diminution of the parts in contact; and, besides, that there would be considerable difficulty in adjusting the axis of the needle so as to be perpendicular to the plane of the graduated circle, or truly horizontal. These considerations induced me to abandon the idea of such a construction. If, however, I am correctly informed, for I have not yet seen the instrument, the dipping

needles now made by Gambey are nearly on this construction; and if so, the practical difficulties which occurred to me have been overcome by him. I have also recently seen a needle on nearly the same principle, which must have been made before Gambey's, since Captain King employed it during his survey of the sea to the north of New Holland: so little idea, however, had the maker of diminishing friction by this means, that the conical ends of the axis of the needle rested in conical caps of brass, until, at my suggestion, agate caps were substituted. By such means, then, the friction on the axis may very probably be diminished, but the difficulty respecting the position of the centre of gravity still remains.

Some years since, Mr. Dollond constructed a needle by which it was proposed to determine the dip without inverting the poles; the errors arising from the excentricity of the centre of gravity being supposed to counterbalance each other, by observing the inclination with the axis of support successively in different positions round the axis of the very acute cones forming the needle. As far, however, as the observations with this needle have come under my notice, they are so widely different from those made at the same places with needles whose poles were inverted, that I greatly suspect the accuracy of the results. Independently of this, the length of time required for the observations is a serious objection to the use of this instrument. Various methods had occurred to me by which the necessity of inverting the poles might be avoided; such as by employing a compound needle, consisting of two needles, moveable about an axis; so that by making observations with the needles separately, and also jointly, in different relative positions, the position of the centre of gravity of each needle, and of the two combined, might be determined: by adjusting small weights to the ends of the needle, by which means the position of the centre of gravity might be adjusted: also by giving two or more axes of suspension to the needle But these methods either led to complicated results, or there appeared practical difficulties in their application. Being, therefore, dissatisfied with them, I had given up the inquiry until very recently, when my attention was again drawn to the subject, by having been consulted respecting the magnetical instruments to be employed on different expeditions, particularly that into the interior of Africa, and that under the direction of Captain Back. I now consider that no practical difficulties will occur in the construc-

tion of a dipping needle on a principle that shall render the inversion of the poles unnecessary, and that a further advantage of such a needle will be, that the observations which give the dip will also give a measure of the terrestrial magnetic intensity, so long as the magnetism of the needle remains unchanged.

Whatever may be the position of the centre of gravity of the needle, there are means by which that position may be determined, previously to the needle being magnetized, and, indeed, after it has undergone that operation. I therefore assume it to be known.

Let, then, g be the distance of the centre of gravity of the needle from the axis of the cylinder or cone at right angles to the plane of the needle forming the axis of support; γ the angle which this distance makes with the magnetic axis of the needle; w the weight of the needle; let δ be the dip, or the angle which the terrestrial magnetic force makes with the horizon; m the force which, acting at the distance $\frac{1}{2}l$ from the centre of the needle, is equivalent to the action of the terrestrial magnetism upon the magnetism of each arm of the needle, so that lm is the static momentum of the terrestrial magnetism acting upon the magnetism of the needle; also let ${}_{\prime}\theta$ be the angle, measured from north downwards, which the axis of the needle makes with the horizon, when the centre of gravity of the needle is downwards, and ${}'\theta$ the corresponding angle when the centre of gravity is upwards: then, whether the supporting axis is considered as a line or as a cylinder, the condition of equilibrium will give the two equations,

$$w\,g\cos({}_{\prime}\theta+\gamma)-l\,m\sin({}_{\prime}\theta-\delta)=0; \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

$$w\,g\cos({}'\theta-\gamma)-l\,m\sin({}'\theta-\delta)=0. \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

From these,
$$\tan\delta=\frac{2\sin{}'\theta\sin{}_{\prime}\theta-\sin({}'\theta-{}_{\prime}\theta).\cot\gamma}{\sin({}'\theta+{}_{\prime}\theta)}, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (a)$$

or
$$\tan\delta=\frac{2-(\cot{}_{\prime}\theta-\cot{}'\theta).\cot\gamma}{\cot{}_{\prime}\theta+\cot{}'\theta} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (b)$$

δ being thus known, we shall have,

$$\frac{l\,m}{w\,g}=\frac{\cos({}_{\prime}\theta+\gamma)}{\sin({}_{\prime}\theta-\delta)}, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (c)$$

or
$$\frac{l\,m}{w\,g}=\frac{\cos({}'\theta-\gamma)}{\sin({}'\theta-\delta)}; \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (d)$$

either of which will be a measure of the terrestrial intensity.

If the value of γ has not been determined previously to the needle being magnetized, it may be determined by inverting the poles of the needle; for when the poles are inverted, two other equations are obtained:

$$w g \cos(\theta' + \gamma) + l m' \sin(\theta' - \delta) = 0, \quad \ldots\ldots\ldots \quad (3)$$

$$w g \cos(\theta_{,} - \gamma) + l m' \sin(\theta_{,} - \delta) = 0, \quad \ldots\ldots\ldots \quad (4)$$

where θ' and $\theta_{,}$ are the values of $_{,}\theta$ and θ' when γ in the equations (1) and (2) is increased by 180°, and m' may or may not be equal to m. From these equations,

$$\tan\delta = \frac{2 - (\cot\theta' - \cot\theta_{,}) \cdot \cot\gamma}{\cot\theta' + \cot\theta_{,}} \ldots\ldots\ldots\ldots \quad (e)$$

Eliminating $\cot\gamma$ from the equations (b) and (e),

$$\tan\delta = \frac{\cot{}_{,}\theta + \cot\theta_{,} - (\cot'\theta + \cot\theta')}{\cot{}_{,}\theta \cot\theta_{,} - \cot'\theta \cot\theta'} \ldots\ldots\ldots\ldots \quad (f)$$

The value of δ being obtained from this equation, the value of γ may be obtained from either of the equations (b) or (e). The angle γ being then determined, either previously to the needle being magnetized, or afterwards by inverting its poles, the dip may, on all subsequent occasions, be determined without having recourse to this process, provided the position of the axis of the needle has been permanent.

The equation (f) is fundamentally the same as that by which the dip is determined from observations with MAYER's needles, but in a form more convenient for computation; but I am not aware that it has ever been proposed to determine the dip by means of these needles, without inverting the poles. Captain SABINE, who seems to have entertained a high opinion of needles of this construction, and who obtained with them extremely accordant results, does not appear to have suspected that the inversion of the poles was unnecessary, after having once ascertained the effect of that operation*. It may be objected to the method I have proposed, that whatever change takes place

* Nearly the whole of this paper had been written before I had an opportunity of consulting MAYER's Memoir, "De Usu accuratiori Acus inclinatoriæ Magneticæ," (Comment. Soc. Reg. Scient. Gotting. 1816,) and I was not aware how nearly some of my views coincided with his. He states that two observations, without inverting the poles, will determine the dip, when it has been ascertained, previously to magnetizing the needle, that its centre of gravity is in the line perpendicular to the axis of the needle and the axis of support. When this is not the case, the dip is determined by four observations, the poles of the needle in the second pair being inverted; and he does not deter-

in the magnetic axis of the needle, in this single operation of inverting the poles, for the purpose of determining γ, will affect the results of all the future observations, since it will affect the value of γ, which will enter in all those results. I am aware of the validity of this objection, and would only have recourse to the method to remedy an omission in the original construction of the needle. But allowing full weight to the objection, it is to be remembered that this operation having to be performed but once, every possible precaution may be taken, in magnetizing the needle, to prevent any deviation of the magnetic axis from the axis of figure; whereas, if the dip is to be determined on

mine the value of the angle γ from the observations which he gives as examples, so that this value might be applied to future observations, without again having recourse to the inversion of the poles. He states that the angle γ may be determined without performing this operation; but I consider that he drew this conclusion without having resolved the equations on which he makes that determination to depend, since those equations will not determine it. He proposes that the instrument should be placed so that the plane of vibration of the needle should be at right angles to the magnetic meridian, and the angles which the needle makes with the vertical being observed, will serve for the determination of γ. Let ${}_{,}\varphi$ and ${}_{'}\varphi$ be the angles which the needle makes with the horizon, when its centre of gravity is downwards, and when the needle is reversed on the axis, in this position of the instrument, these angles being measured from the same point; then the condition of equilibrium will give the two equations,

$$w g \cos ({}_{,}\varphi + \gamma) + l m \sin \delta \cos {}_{,}\varphi = 0,$$
$$w g \cos ({}_{'}\varphi - \gamma) + l m \sin \delta \cos {}_{'}\varphi = 0,$$

which are equivalent to those given by MAYER, though our notations are different.

From these two equations we should have

$$\sin ({}_{,}\varphi + {}_{'}\varphi) \cdot \sin \gamma = 0.$$

So that γ remains undetermined, and ${}_{,}\varphi + {}_{'}\varphi = 180$ or 0, or the observed angles ${}_{,}\varphi$ and ${}_{'}\varphi$, are supplemental to each other, the two equations being only equivalent to one.

If we take the two equations

$$w g \cos ({}_{,}\delta + \gamma) - l m \sin ({}_{,}\delta - \delta) = 0,$$
$$w g \cos ({}_{'}\theta - \gamma) - l m \sin ({}_{'}\theta - \delta) = 0,$$

and one of the preceding equations,

$$w g \cos ({}_{,}\varphi + \gamma) + l m \sin \delta \cos {}_{,}\varphi = 0,$$

we shall obtain the equations

$$(\cot {}_{,}\theta - \cot {}_{,}\varphi) \cdot \tan \delta + \cot {}_{,}\varphi \cot \gamma - 1 = 0,$$
$$(\cot {}_{'}\theta + \cot {}_{,}\varphi) \cdot \tan \delta + \cot {}_{,}\varphi \cot \gamma - 1 = 0:$$

whence

$$\cot {}_{,}\theta - \cot {}_{'}\theta - 2 \cot {}_{,}\varphi = 0,$$

giving the relation between the angles ${}_{,}\theta$, ${}_{'}\theta$, and ${}_{,}\varphi$; γ remaining undetermined as before.

all occasions by inverting the poles, the same care and the same precautions must be taken on all occasions, to ensure accuracy, when probably circumstances are most unpropitious.

Although I consider that, in the method I propose, the not changing the magnetism of the needle will be of great advantage in the determination of the dip, a further and still greater advantage which will arise from it will be that we shall, in consequence, obtain a measure of the intensity of terrestrial magnetism. As far as this intensity can be determined by means of an individual needle, the accuracy of the result in all cases depending upon the permanency of the magnetism in the needle, it will be determined from the equations (*c*) and (*d*), by the observations which give the dip, and by this means observations of the most tedious nature will be avoided. In order, however, to attain this object, it is necessary that the centre of gravity of the needle should not be in the centre of figure; and what was considered to constitute perfection in a dipping needle, would render it useless for this purpose; nor must the centre of gravity be in any other point in the magnetic axis of the needle; but the intensity may be determined if it be in any other position, though not equally well from all.

As a dipping needle is an instrument to be employed at places situated on south as well as on the north side of the magnetic equator, it is necessary to have regard to this, in fixing upon a position for the centre of gravity. In order that the position of this point should equally affect the dip on both sides of the equator, it must be in a line at right angles to the axis of the needle and the axis of motion, that is, the angle γ must be 90°; in which case the needle would still be parallel to the horizon at the magnetic equator. The equations (1) and (2) will in this case become

$$w g \sin \beta - l m \sin (\delta - \beta) = 0, \quad \ldots \quad (5)$$

$$w g \sin {}'\theta - l m \sin ({}'\theta - \delta) = 0; \quad \ldots \quad (6)$$

and $$\tan \delta = \frac{2 \sin {}'\theta \sin \beta}{\sin ({}'\theta + \beta)}, \quad \ldots \quad (g)$$

or $$\cot \delta = \frac{\cot \beta + \cot {}'\theta}{2}; \quad \ldots \quad (h)$$

also $$\frac{l m}{w g} = \frac{\sin \theta}{\sin (\delta - \beta)} \quad \ldots \quad (i), \qquad \text{or } \frac{l m}{w g} = \frac{\sin {}'\theta}{\sin ({}'\theta - \delta)} \quad \ldots \quad (k)$$

The principle on which the value of g depends, is not of such ready application as that on which we have determined the value of γ. The magnetic intensity at any place is generally referred to that at the magnetic equator, which is taken as unity. In order, therefore, that this may be the case with any particular needle, we must have

$$lm = wg, \text{ when } \delta = 0.$$

In this case the equations (5) and (6) become

$$(wg + lm) \sin {}_{,}\theta = 0, \text{ and } (wg - lm) \cdot \sin {}_{'}\theta = 0.$$

So that ${}_{,}\theta = 0$, and ${}_{'}\theta$ is indeterminate.

In order, then, that the condition of $\frac{lm}{wg}$, which is the measure of the intensity, being equal to unity at the magnetic equator, should be fulfilled, it is necessary that the needle, when there, should be horizontal with its centre of gravity downwards, and that it should rest in any position when reversed on its axis of motion. It therefore becomes a question how the position of the centre of gravity of a needle can be adjusted, in a place at a distance from the magnetic equator, so that when the needle is carried there, it shall be horizontal with the centre of gravity downwards, and indifferent to position when reversed on the axis, or so that in this case $\frac{lm}{wg}$ should be equal to unity. If we knew the law according to which the magnetic intensity varies, this might easily be accomplished; but it is to determine this law that observations are required; and we can only avail ourselves of one which does not very closely accord with observation. This law, deduced from the hypothesis of two magnetic poles near the earth's centre, is that the intensity varies inversely as $\sqrt{(4 - 3\sin^2\delta)}$; from which, if the intensity at the equator is unity, we shall have

$$\frac{lm}{wg} = \frac{2}{\sqrt{(4 - 3\sin^2\delta)}}$$

and consequently

$$\frac{\sin {}_{,}\theta}{\sin(\delta - {}_{,}\theta)} = \frac{2}{\sqrt{(4 - 3\sin^2\delta)}}, \text{ and also } \frac{\sin {}_{'}\theta}{\sin({}_{'}\theta - \delta)} = \frac{2}{\sqrt{(4 - 3\sin^2\delta)}}.$$

From these equations we obtain

$$\cot {}_{\prime}\theta = \cot\delta + \tfrac{1}{2}\sqrt{(4\cot^2\delta + 1)},$$
$$\cot {}_{\prime\prime}\theta = \cot\delta - \tfrac{1}{2}\sqrt{(4\cot^2\delta + 1)}.$$

So that knowing the dip at any place, the angles ${}_{\prime}\theta$, ${}_{\prime\prime}\theta$, which the needle ought to make with the horizon, in order that, according to the assumed law, the condition at the equator should be fulfilled, may be determined.

According to this adjustment of wg to lm, $\cot {}_{\prime\prime}\theta$ would always be negative, or ${}_{\prime\prime}\theta$ greater than 90°. It would therefore, in practice, be more convenient to measure the inclination of the needle in this case from the opposite point of the horizon to that from which ${}_{\prime}\theta$ is measured. Taking, then, φ for this inclination, or $\varphi = 180 - {}_{\prime\prime}\theta$, the equations (h) and (k) would become

$$\cot\delta = \frac{\cot {}_{\prime}\theta - \cot\varphi}{2}, \qquad \frac{lm}{wg} = \frac{\sin\varphi}{\sin(\delta + \varphi)}.$$

Although the condition of adjusting the centre of gravity in the perpendicular to the two axes is not one of great practical difficulty, yet it becomes difficult when it is also required that, after being magnetized, the needle shall assume certain positions; and it will scarcely admit of accomplishment without some moveable weight being attached to the needle for the purpose of adjustment. To this there is a serious objection, unless the weight can be permanently fixed, after the required adjustment has been effected. But these are practical difficulties which are not insurmountable, and indeed the second condition is not necessary, in order that what is required may be effected with the needle; I shall, however, have occasion to point out a circumstance which will have an influence on that condition, independent of the construction of the needle.

However correct may be the proposed principles of construction, the instrument may fail in its practical object, in consequence of the changes in the angles measured by it being considerably less than corresponding changes in the dip, so that a small error of observation would introduce a considerable error in the result. Although this may, to a certain extent, appear to be the case, yet it is only so when the errors of the corresponding observations tend both the same way; and even then, except in particular situations, the errors are not much increased. Supposing the centre of gravity of the needle to have

been adjusted as I have stated, then if the dip is 69° 40′, (nearly that in London at present,) we shall have $\beta = 45° 12'$, $\varphi = 75° 52'$, M = 1·7134; an error + 5′ in β, and − 5′ in φ, will give the dip 69° 46′, and M = 1·7141; an error − 5′ in β, and + 5′ in φ, will give the dip 69° 33′, and M = 1·7128; an error of ± 5′ in β alone will introduce an error of ± 4′ in the dip; an error of ± 5′ in φ alone will introduce an error of only ∓ 2; and if the errors in β and φ are both plus or both minus, the errors in the dip will be further diminished. An error, then, of 5′ in each of the angles, even when both tend the same way, will only introduce an error of 6′ or 7′ in the dip, and of ·0007 in the intensity. With whatever instruments the dip may be determined, it rarely happens but that the observed angles differ from each other by much more than this; and I doubt whether, taking all circumstances into account, the intensity is ever determined nearer than to the second place of decimals by the method of vibrations.

As the dip decreases, the angle β will decrease, and the angle φ will approximate to 90°; and within two or three degrees of the magnetic equator, φ would be so nearly 90°, that $\cot\delta$ might, without sensible error, be taken equal to $\frac{1}{2}\cot\beta$. If λ is the magnetic latitude, then the formula $\tan\delta = 2\tan\lambda$ would give $\lambda = \beta$ near to the equator; and in other positions we should have $\cot\lambda = \cot\beta - \cot\varphi$.

I have already mentioned that it had long since occurred to me, to place two needles on the same axis, at a distance from each other, but so as, however, to form one compound needle, and that I had made the calculations from which the dip might be obtained by means of such a needle, without the necessity of inverting the poles; but that I gave up the idea, in consequence of the complicated form of the results, when the positions of the centres of gravity of the needles were undetermined. If, however, the two needles were made of exactly the same weight, and the centre of gravity of each were accurately adjusted in the line perpendicular to the axis of the needle, and so that those centres should be at equal distances from the centre of motion, such a needle would possess many advantages; it would, however, be necessary, for the purposes of adjustment and of more accurate observation, that the instrument should have two graduated circles, one for each needle.

If the needles were placed on the axis, so that their contrary poles should be

adjacent, and their axes in the same plane, then, when the centres of gravity of the two needles are on the same side of this plane, the needle should be horizontal; and when on contrary sides, the needle should be indifferent to position. By this means the accuracy of the adjustments might be ascertained.

If the needles were placed on the axis of motion, so that their axes should be at right angles to each other, then they would admit of eight different arrangements with respect to their centres of gravity; four of these having, however, precisely the same reference to one needle which the remaining ones have to the other, or simply arising from reversing the position of the axis of motion. By observing the inclination of the needle in these different arrangements, taking the mean of two corresponding angles as the inclination, we should obtain four equations; and from any two of these, the dip and the ratio of the static momentum of the force of terrestrial magnetism on that of the needle to the static momentum of the needle's weight might be deduced. By taking a mean of the several results, the dip and the measure of the magnetic intensity would be determined, nearly free from errors of adjustment.

In this case, the centre of gravity of each needle will be in the axis of the other. C indicating the centre of the compound needle, M, $M_{,}$, the marked ends of the two needles; G, $G_{,}$, their centres of gravity; let ε be the inclination of C M to the horizon when G is between $M_{,}$ and C, and $G_{,}$ between M and C; θ its inclination when G is between $M_{,}$ and C, and $G_{,}$ is beyond C; φ its inclination when G is beyond the centre, and $G_{,}$ between M and the centre; ψ its inclination when G and $G_{,}$ are both beyond the centre; also $w\,g$ the static momentum of the weight of each needle, and $l\,m$ that of the force of terrestrial magnetism acting on the magnetism of each needle; then the condition of equilibrium will give,

$$w\,g\,(\cos\varepsilon-\sin\varepsilon)-l\,m\,\{\cos(\delta-\varepsilon)-\sin(\delta-\varepsilon)\}=0 \quad . \quad . \quad . \quad . \quad (\text{I.})$$
$$w\,g\,(\cos\theta+\sin\theta)+l\,m\,\{\cos(\delta-\theta)-\sin(\delta-\theta)\}=0 \quad . \quad . \quad . \quad . \quad (\text{II.})$$
$$w\,g\,(\cos\varphi+\sin\varphi)-l\,m\,\{\cos(\delta-\varphi)-\sin(\delta-\varphi)\}=0 \quad . \quad . \quad . \quad (\text{III.})$$
$$w\,g\,(\cos\psi-\sin\psi)+l\,m\,\{\cos(\delta-\psi)-\sin(\delta-\psi)\}=0 \quad . \quad . \quad . \quad (\text{IV.})$$

From these the following values of $\cot\delta$ are obtained:

$$\cot\delta=\frac{1-\tan\varepsilon}{1+\tan\theta}; \qquad \cot\delta=\frac{\cot\varepsilon-1}{\cot\varphi+1}; \qquad \cot\delta=\frac{(1-\tan\varepsilon).(1-\tan\psi)}{1-\tan\varepsilon.\tan\psi};$$

$$\cot\delta = \frac{1-\tan\psi}{1+\tan\varphi}; \quad \cot\delta = \frac{\cot\psi - 1}{\cot\theta + 1}; \quad \cot\delta = \frac{1-\tan\theta\,.\,\tan\varphi}{(1+\tan\theta)\,.\,(1+\tan\varphi)}.$$

The third and sixth may be put in the forms

$$\cot\delta = \frac{\cos(\varepsilon-\psi)-\sin(\varepsilon+\psi)}{\cos(\varepsilon+\psi)}; \quad \cot\delta = \frac{\cos(\theta+\varphi)}{\cos(\theta-\varphi)+\sin(\theta+\varphi)},$$

somewhat more convenient for computation.

Substituting the mean of the values of δ, thus obtained, each of the equations I., II., III., IV., will give a value of $\frac{lm}{wg}$; the mean of which values will give the measure of the magnetic intensity.

If the axes of the needles were again brought into the same plane, so that the corresponding poles should be adjacent, then the dip might be obtained either by direct observation, or by computation from the equation (h), according as the centres of gravity of the two needles are on contrary sides, or on the same side of the plane of the axes.

When the centres of gravity are on contrary sides of the plane of the axes, if the adjustment have been correctly made, the centre of gravity of the compound needle will be in the centre of motion, and the observed inclination will be the dip; but if small errors, as must almost necessarily happen, have been made in these adjustments, then, without changing the face of the instrument, four arrangements of the needles upon the axis may be made, and four others by reversing the ends of the axis; and the mean of the inclinations will be the dip, freed from these errors of adjustment. The errors of the instrument itself will, as usual, be counteracted by making corresponding observations with its face reversed.

The axes of the needles being still in the same plane, if the centre of gravity of each be on the same side of that plane, then, by varying the arrangement of the needles and of the axis, four observations may be made with the centre of gravity of the compound needle upwards, and four others with it downwards. From these the dip may be obtained by means of the equation (h), and the intensity by means of the equations (i) and (k), freed from errors of adjustment.

We should thus, with the same needle, obtain the dip by three independent methods, and a measure of the magnetic intensity by two such methods, and

their agreement would be a test of the accuracy of the adjustments and of the observations. If a compound needle of such a construction were very accurately made, I consider that it would give accordant and, therefore, very satisfactory results; but, at the same time, I am quite sensible that it would require great care and delicacy in the adjustment of the needle, and in making the observations.

As I am upon the subject of improvements in the dipping needle, it is proper that I should mention one which I had not seen until within a few days, and which has just been completed by Mr. Bate, on a principle suggested, as Captain Beaufort informs me, by Lieutenant Barnett, namely, that the support of the needle should be a knife-edge*. It being necessary that the knife-edge should always have the same position, the needle is moveable on a projecting axis, whose centre is coincident with the edge, and on the other end is fixed a counterpoise to the needle, in the form of a brass needle, which, when horizontal, indicates that the sides of the knife-edge are equally inclined to the agate plane on which it rests, between the magnetized needle and its counterpoise. The knife-edge is to be adjusted so as to pass through the centre of gravity of the whole; and when this is effected, the dip will be obtained without inversion of the poles of the needle. This adjustment must be a matter of great delicacy in the first instance; but if it can be effected, and its permanence ensured, there is every reason to expect that the observations with this needle will not only be more accordant with each other than those obtained with needles supported on cylindrical axes, but that the results will be nearer to the truth.

A considerable defect in this construction, however, is, that the counterpoise acts as dead weight, doubling the inertia of the needle without adding to its power. If a counterpoise simply to the knife-edge were attached to its middle point, the correct position of that edge on the agate planes being determined by a small index above, and the two needles, of the compound needle which I have described, were placed on cylindrical ends, projecting from the knife-edge so that the axes of the cylinders should coincide with it, the needles would act as counterpoises to each other, and with the increase of inertia

* M. Kupffer mentions having made some observations with a needle supported on a knife-edge, but does not describe the instrument. London and Edinburgh Philosophical Magazine and Journal, third series, vol. i. p. 130.

there would be a corresponding increase of power. The adaptation of the knife-edge to the construction which I have described would be a decided improvement; and in this construction the difficulties which must occur in adjusting the knife-edge to the centre of gravity would be avoided. I should therefore propose, if this construction be adopted, that to the knife-edge a counterpoise should be attached, so as to pass freely between the agate planes on which the edge rests. The knife-edge should then be accurately adjusted to the counterpoise, so that the edge should pass through the centre of gravity of the whole. Two needles, of precisely the same form and weight, such as I have before described, are then to be applied to the axes projecting from the knife-edge; and I consider that little practical difficulty would occur in adjusting the centre of gravity of each, very accurately, to the line perpendicular to its axis. The opening in the centre of each needle might be of the form of two truncated cones joined by their smaller ends, which would allow of the axes projecting from the knife-edge being conical, and, at the same time, admit of the needles being reversed on these axes. The two agate planes should be bedded in the same piece of metal, and then worked truly in one plane. The sensibility of such a needle would be much greater than that of any hitherto made, and the utmost delicacy would be required in the adjustments for observation; but if the needle were accurately constructed, and due care were taken in the magnetizing and in making the adjustments and observations, I confidently expect that the dip and intensity would be obtained, by such means, to a degree of certainty hitherto unattained.

The principle, then, on which I propose that a needle should be constructed, whether a single needle, or each needle of the compound needle, is, that it should have an additional weight (a small platinum stud, for instance,) fixed in the line perpendicular both to the axis of the needle and to that of motion, and the whole so adjusted that the centre of gravity be likewise accurately in this line. This additional weight is also to be so adjusted to the magnetism of the needle, that at a place where the needle is horizontal with the weight downwards, (on the magnetic equator,) it shall be nearly indifferent to position when reversed on the axis. Although this condition could only be accurately fulfilled by making these adjustments at the magnetic equator, and even here it would only obtain with an invariable temperature, yet I have shown how such

an adjustment may be approximately made at any place where the dip has been determined. Perhaps, for an instrument intended for observation near the magnetic equator, it would be advisable to have two needles, one having the additional weight so adjusted to the needle's magnetism, that at the equator $w\,g$ should be equal to $l\,m$, and the other so that $w\,g$ should be equal to $2\,l\,m$, in order to obviate the degree of indecision that might, in that situation, occur in the direction of the needle; but the necessity or utility of this would be best ascertained by actual observation.

The advantages attending the use of such a needle would be, that the dip would be obtained without reversing the poles of the needle; by which means the result would be not only less liable to error than when that operation is necessary, but the observation would be made in less than half the time usually required: that a measure of the intensity of the terrestrial magnetism would be obtained from the same observations which give the dip: that thus the intensity of the force would not only be obtained by means of the same needle, but also at the same instant as that at which its direction is determined. So that by this means comparative results would be more correctly obtained, and in less time, by one observer, than could be obtained by two, if the intensity were determined by the vibration of a needle. As compared with the single needle, the compound needle which I have described would have the advantage, that with it the adjustments might be verified; that independent results might be obtained; that it would possess greater sensibility, and give more accurate results; and that with it the dip and intensity might be obtained near the magnetic poles, or near the equator, as in other situations. Whether these advantages might not be counterbalanced by the greater nicety required in the adjustments, the longer time for observation, and the greater liability to derangement, can only be determined by actual observation with needles of each construction.

In a paper published in the Philosophical Transactions for 1825, I first investigated the effects which change of temperature produces on the intensity of the magnetism of steel bars, in order to apply the results to the correction of observations which I had made for determining the diurnal changes in the horizontal intensity of terrestrial magnetism. In the same paper I pointed out the necessity of applying such a correction for the difference in the tempera-

tures at which observations of the vibrations of a needle are made, in order that the times of vibration should be reduced to the same temperature*. Although such a correction has since been applied by Professor HANSTEEN, Captain SABINE†, M. KUPFFER‡, M. QUETELET§, and others, yet, as it depends upon the individual needle employed, the application of any formula must be doubtful, unless deduced from experiments with that needle. The method which I have proposed for determining the terrestrial magnetic intensity, would also require that a correction should be applied for the difference in the temperatures at which the observations may be made; and I consider it would be desirable that experiments should be made with the needle, in order to determine the nature of the corrections to be applied, previously to making any observations for the dip or intensity. In the same paper, I have stated, that if a magnet is subjected to a temperature above a certain degree, about 100° FAHR., a portion of the magnetism is destroyed‖: I consider that this circumstance might be taken advantage of to adjust the magnetism of the needle to its static momentum, in the ratio required.

It must not be supposed, because I have proposed a very different method, that I am insensible to the advantages to be derived from that proposed by Professor GAUSS, for determining the terrestrial magnetic intensity. I greatly admire the sagacity he has shown in devising means by which an absolute measure of the horizontal force is to be determined; and consider that his methods may, very probably, be advantageously employed in an observatory, where the apparatus remains undisturbed. They may be the means of determining, not only the course of the daily variation of the horizontal force, but the changes which may take place in its intensity in long periods of time. However, although, mathematically considered, the solution of the problem of the determination of the measure of the horizontal force may be complete, yet I foresee many difficulties in the practical application; and without having seen a full account of Professor GAUSS's method, with the experimental details, it is not possible to decide how far these may have been overcome. By the vibrations of a bar A, Professor GAUSS determines the product of the terrestrial

* Philosophical Transactions, 1825, p. 61. † Philosophical Transactions, 1828, p. 4.
‡ Voyage dans le Caucase, p. 82. § Mémoires de l'Académie de Bruxelles, 1830, tom. vi. p. 8.
‖ Philosophical Transactions, 1825, p. 63.

intensity by the static momentum of the free magnetism of A. By introducing a second bar B, and by observing at different distances the joint effects of A and of the terrestrial magnetism on B, he proposes to determine the ratio of the terrestrial intensity to the static momentum of the free magnetism of A. Now, if the temperature of A is not the same in the second set of observations as it is in the first, neither will the static momentum of its free magnetism be the same; so that on this account the first observations would give the product of two quantities different from those of which the ratio is obtained from the second; and independently of this source of error, the intensity of terrestrial magnetism is itself changing during the time which must necessarily be employed in making the observations. These considerations make me doubt whether a very accurate measure of the horizontal intensity will be obtained by this method, even in an observatory; and I think it could not, where an apparatus has to be moved from one station to another, be successfully applied, both on this account and on account of the delicacy of the preparatory observations, and of the time requisite for making them, in addition to that required for the observations by which the terrestrial intensity and its variations are to be determined. Some time, I also consider, must elapse before we can expect to find many observers who will be able to obtain, by this method, results from which can be deduced conclusions on whose correctness we can rely. It is likewise to be remembered, that however accurate may be the measure of the terrestrial magnetic force obtained by this method, it is only the resolved part of that force parallel to the horizon which is determined; and that in order to obtain the total force, the object of our research, the dip, determined by some means, must enter as an element. This is also the great objection to the use of Professor Hansteen's apparatus, which is unrivalled for portability and convenience of use: the accomplishment, however, by its means, of the object proposed by Professor Gauss was never contemplated, and is indeed beyond its power, without the application of a second needle.

Royal Military Academy,
April 8th, 1833.

XIX. *Observations of Nebulæ and Clusters of Stars, made at Slough, with a Twenty-feet Reflector, between the years* 1825 *and* 1833.

By Sir John Frederick William Herschel, *Knt. Guelp. F.R.S. &c.*

Received July 1,—Read November 21, 1833.

THE following sheets contain the results of observations begun about the year 1825, and prosecuted with more or less assiduity from that time up to the commencement of the present year, in pursuance of a design to review the nebulæ and clusters of stars discovered by my father; and perhaps, in so doing, to add to their number, and to extend in some degree our knowledge of the nature and physical construction of that mysterious and interesting class of bodies. It was my original intention to have deferred the publication of these observations until I should have been able to have presented their results to the Royal Society in the more complete form of a general catalogue of nebulæ and clusters visible in this latitude; in which all my father's nebulæ should have been included, and their places determined by at least two observations. To have done this, however, would have required several years' additional work; and the want of an extensive list of nebulæ arranged in order of right ascension, having, since the recent improvements in the achromatic telescope, and the increased assiduity of astronomers in the detection and observation of comets, become continually more pressing, and the deficiency more and more complained of, I have thought it on the whole a preferable course to supply that deficiency so far as I am able, not by the production of a catalogue pretending to a precision and a completeness I am unable yet to give it, but by simply stating the individual results of such observations as I have hitherto made; with no other preparation than that of reducing them all to a common epoch, arranging them in order of right ascension, and bringing together, in every case where the same object has been more than once observed, all the observations of it which occur. By so doing, two distinct ends are accom-

plished. In the first place, the series of observations thus arranged can be used, as a catalogue, for reference, and may serve the purposes of one, until a more perfect one can be produced—(*valeat quantum*). In the next place, the results so stated, carry with them their own weight and evidence. Where several observations of one and the same object occur, their agreement or disagreement will enable every one to assign to them their proper degree of credit,—to appretiate the amount of error, both accidental and inherent, to which the system of observation adopted is liable; and being thus impressed with a due notion of the degree of latitude with which each result is to be interpreted, he will readily perceive what reliance can be placed on single observations, unchecked by the context.

My mode of observing,—the general character of the instrument employed, and the principal sources of error to which its determination of the places of objects is liable, are stated in considerable detail in my five catalogues of double stars discovered with it, published in the Memoirs of the Astronomical Society. To these, therefore, I will refer for the particulars in question: but it will be right here to mention, that a much greater latitude of error must unavoidably subsist in observations of nebulæ than in those of stars. Many of these objects present a large and ill-defined surface, in which it is not always easy to say where the centre of greatest brightness is situated. Vast numbers of them are so extremely faint as to be with difficulty discerned at all, or not until they have been some time in the field of view, or are even just about to quit it. In such cases the observations become hurried and uncertain; and this peculiar and fertile source of error and mistake is greatly increased by their excessively irregular distribution over the heavens,—crowded together in some places so as to allow hardly any interval between their transits,—while in others whole hours elapse without a single nebula occurring in the zone of the heavens under examination. In these crowded parts of the heavens, it is not only the number, but the variety and interest of the objects which distract attention and render it scarcely possible to proceed with that methodical calmness and regularity which is necessary to ensure numerical correctness, especially when the observer has continually present to his mind the rarity of his opportunities. It is only in the months of March, April, and May that the richer parts of the heavens can be advantageously observed, and

then only in the *complete* absence of the moon, and of twilight. When to these conditions we add those which arise from the variable and uncertain nature of our climate, it will be seen that a number of circumstances by no means frequently concurring, is necessary to produce a night in which it is possible to make any great progress in a review of nebulæ; and that in fact there is hardly any branch of astronomy which has a greater tendency to create a sense of hurry, of all things the most fatal to exact observation.

The observations which are here registered comprise, more or less, about 2300 ~~2500~~ nebulæ and clusters of stars, which is the number of those observed by my father; but of the two collections, only about 1800 ~~2000~~ are common to both, the remaining 500 of mine being new. It may serve to show the close and rigorous nature of my father's scrutiny, when I state, that among these 500 I can call to mind only one very conspicuous and large nebula, and only a very few entitled to rank in his first class, or among the "bright nebulæ." By far the greater proportion of them are objects of the last degree of faintness, only to be seen with much attention and in good states of the atmosphere and instrument. This is so far satisfactory, that it shows pretty evidently our knowledge of the nebulous contents of the northern hemisphere to be at length nearly complete, and that to make a further step, the powers of an instrument like the 40-feet reflector will be required.

It has generally been my practice to make some kind of sketch or drawing, sometimes more, sometimes less elaborate, of any nebula at all remarkable which presented itself. In many instances careful drawings have been made and repeatedly compared, at distant intervals, with the objects they have been intended to represent. The difficulty of making satisfactory representations of such objects is, however, extreme; and of those which accompany this paper, as specimens of the various classes of objects which the heavens present, I am rather disposed to apologize for the incorrectness than to vaunt the accuracy. General resemblance, however, I can vouch for; and where fidelity in details has been attempted, I should hope that glaring departures from nature will hardly be found to subsist. Among the figures will be found representations of some very extraordinary objects, which have not hitherto been sufficiently pointed out to the notice of astronomers, and of which indeed some of the

most remarkable peculiarities have escaped every former observer. These are briefly noticed in the descriptions appended to each observation, and more distinctly and at large in the explanations of the plates. Meanwhile it is only necessary for any reader to cast his eye over the figures, to be satisfied that many of these mysterious objects possess a symmetry of parts, and a unity of design, which, singular as their constitution must appear, strongly mark them as systems of a definite nature, each complete in itself, and subservient to some distinct purpose of which it is in vain for us to conjecture the nature.

The manner in which the observations are presented in the following pages requires little explanation. The first column contains a general number for convenience of future reference; the second, the number or name under which each nebula is to be found, either in my father's catalogues (in which case his class and number is set down,) or in the brief but important list furnished by Messier in the Mémoires de l'Académie des Sciences for 1771, and the Connoissances des Temps for 1783 and 1784, which are indicated by the letter M. When no previous mention of a nebula or cluster could be found in the writings of former observers, it is designated as *Nova*. A very few are due to Struve. These are noted by Σ.

The third column contains the right ascension, and the fourth the north polar distance, for 1830·0. The manner in which these elements are obtained from the rough observations, or the process of reduction employed throughout the work, will be fully stated in an Appendix annexed to the observations, as well as other matters of detail which may be advantageously deferred. Under the head of each nebula, as above mentioned, all its observations are brought together, and for distinctness' sake, the hour and minute in $\mathcal{R}$, and the degree in N.P.D. are only once set down for each, viz. in the upper line, or that which contains the earliest $\mathcal{R}$ of each. When the subsequent observations in $\mathcal{R}$ fall into the next minute, the seconds are counted on beyond 60; and when those in polar distance pass into the next degree, the same contrivance, i. e. counting the minutes beyond 60, is resorted to, to avoid doubling the initial entries and so misleading the eye. When no $\mathcal{R}$ or no P.D. has been observed, the fact is indicated by dotted lines. When only a rough approximation has been obtained (a case unfortunately too common), or when, none having been procured, the

necessary datum has been taken from the working list book, this is indicated by the sign $\pm$. What is here meant by the working list will be explained in the Appendix.

The column headed "Description and Remarks" contains the abbreviated description taken down, at the time of observation, from the sweeping book. The following is the system of abbreviation used.

B	denotes	Bright.	l	denotes	long *or* little.
b	———	brighter.	M	———	in the middle.
br	———	broad.	m	———	much.
c	———	considerably.	N	———	nebula.
Cl *or* cl	———	cluster.	neb	———	nebulous *or* nebulosity.
comp	———	compressed.	n	———	north.
D *or* d*	———	double star.	p	———	pretty, preceding.
E	———	extended, elliptic, *or* elongated.	pos	———	angle of position.
e	———	extremely, excessively.	R	———	round.
F	———	Faint.	r	———	resolvable.
f	———	following.	S	———	small.
fig	———	figure.	s	———	south, suddenly.
g	———	gradually.	st	———	star, stars.
i *or* irr	———	irregular.	sc	———	scattered.
L	———	large.	v	———	very.

* Star.
☾ Moon above the horizon.
☾☾ Moon very troublesome.
⊕ Globular cluster.

In all the descriptions the following order is, or ought to be, adhered to. First the degree of brightness is mentioned, characterized by e B, v B, p B, B, p F, F, v F, e F. Next, the size, generally indicated by L and S with their adverbial adjuncts e, v, p. Thirdly, the general form, as R, E, m E, &c. Fourthly, the degree and rate of condensation, as b M, s b M, v g l b M, &c. If the nebula be resolvable, it is next expressed by r. After these come more distinct numerical particulars, as the estimated diameter, indicated by the number of seconds it was judged to subtend; the measured, or estimated length, breadth, or position with the meridian, &c.; and any other remarks which may have appeared desirable to note at the time. Clusters are characterized as Rich, or poor, or compressed, loose, or scattered, &c. For example:—

"v B; v L; l E; v g p m b M; 50″ l; 45″ br; pos 29°·3 by microm. a ✳ 9 m 45° n p dist 80″." Which expanded runs thus:

"Very bright; very large; little extended; very gradually pretty much brighter in the middle; 50″ long; 45″ broad; angle of position (reckoned always from the north, and from a meridian, in the direction north, following, south, preceding,) measured 29°·3 by the micrometer. A star of the ninth magnitude is situated 45° north preceding the centre of the nebula, and at a distance from it of 80″, (both by estimation)." *Measured* angles are always marked as above, in degrees and decimals.

Finally, the last column contains the sweep in which the observation occurs, numbered regularly on in order of time up to sweep 427, with only one interruption of the order, viz. that the sweeps marked 43, ... 49 precede sweep 1 in order, having been written down on separate sheets in the year 1823, before the commencement of my more regular plan of observation, and mislaid.

Observations of Nebulæ and Clusters of Stars.

No.	Synonym.	R 1830·0.	N.P.D. 1830·0.	Description and Remarks.	Sweep.
		h m s	° ′ ″		
1	III. 868	0 0 1·6	86 19 58	Very Faint (v F); Large (L); very gradually a little brighter in the middle (v g l b M); 40″ in diameter (40″).	95
		2·5	19 21	Bright (B); Small (S); very suddenly much brighter in the middle (v s m b M); 12″ long; much extended (m E); a star precedes.	300
2	III. 866	0 0 2·0	57 30 40	No description	102
		4·7	30 51	Small stars and nebulosity	104
3	II. 591	0 0 3·0	75 8 37	e F; R; b M; a star 10 m, n p, dist. 5′	174
		3·6	7 41	e F; R; v g v l b M; 40″	175
		7·5	7 23	F; R; v g b M; 60″	11
		...	.....	v F; R; l b M	1
4	Nova?	0 0 19·6	63 13 29	p B; R; b M; 20″ (? if not IV. 15)	172
5	IV. 15	0 1 50±	63 15 0	A star 15 m with a burr R from Cat	178
6	II. 853	0 1 58·5	57 35 27	p B; p L; irreg fig; (very clear sky)	106
		59·8	35 33	p B; E	100
7	III. 861	0 3 32·6	59 54 15	No description	102
		36·9	53 31	p F; L; R; (very foggy)	104
		...	54 30:	e F; S; R	178
8	IV. 58	0 3 52·5	18 25 17	A * 10 m with strong neb atmosph 15″ diameter. Exactly R and p suddenly fading away makes a D * class 5 with a * preceding.	378
		55·5	25 24	The L * of a D * strongly affected with a neb burr. Pos 241°·4; Δ R = 25ˢ; 10 and 12 m.	380
		59·4	25 43	A star 11 m with a luminous atm 30 or 40″ diam	228
9	Nova.	0 4 12·4	60 1 48	e F; has * 12 m 45″ dist; pos 325°?	100
10	Nova.	0 4 26·5	59 39 22	e F; v S; not to be seen but in the clearest night	106
11	III. 183	0 6 23±	72 24 21	v F; S; E	92
12	Nova.	0 6 36·4	78 30 ±	About this place a considerable space seems affected with nebulosity.	14
13	II. 241	0 6 45·4	73 36 50	B; S; s b M	92
14	III. 428	0 7 42·6	97 15 48	F; R; p s b M; 15″	186
15	V. 16	0 9 32·8	60 52 10	An extr F cluster with neb 5′ diam. Several * s 15...18 m. Seen distinctly, but there is also unresolved neb.	178
16	Nova.	0 12 21·6	68 34 46	F; S; R; p s b M; 15″	166
17	Nova.	0 12 32·1	68 29 16	E; perhaps bicentral; makes trapezium with three B stars	166
18	Nova.	0 13 36·8	61 11 30	F; R; g b M; 15″	178
19	II. 257	0 13 37·2	80 27 49	v F; p L; R; g b M	15
20	Nova.	0 16 0·2	29 36 39	A p S, p compressed cl; 3′ diam st 11...18 m in 2 or 3 principal branches. If this be VI. 35, there must be a mistake in my father's obs or mine of 6^m in R.	216

No.	Synonym.	Æ 1830·0.	N.P.D. 1830·0.	Description and Remarks.	Sweep.
		h m s	° ′ ″		
21	III. 148	0 17 5·4	61 43 52	Not v F; p L; R; b M; 40″. Seen in moonlight	114
		5·8	43 46	p B; R; p s b M; 20″	178
22	Nova.	0 17 36·6	19 33 2	A v loose, p rich cl; ✻s 9…12 m; ✻ 9 m in M taken	378
23	III. 869	0 20 6·5	88 5 38	v F; S; close to a d ✻. The s p of two	95
		9·0	6 27	F; S; b M; n f a d ✻; the s p of two neb	93
24	VIII. 79	0 20 27·1	30 43 3	A ✻ 9 m about M of a v L, coarse sc rich cl of ✻s 9…13 m which more than fills field.	213
25	II. 854	0 20 31·5	88 4 18	p B; 1 E in meridian; the n f of two	95
		33·4	4 57	B; E; b M; 20″	93
26	II. 855	0 21 27·3	88 51 16	p B; R; b M; (, yet a p good obs	108
		27·8	51 14	e F; b M; has a s ✻ 3′ dist; pos 150°±	110
		28·7	51 4	p F; R; 1 b M; 25″; a good obs	113
		…	54 4 : :	Excess F (and haze. P D no reliance; much past meridian when taken, and wanting a great correction.	93
27	Nova.	0 23 5·8	96 5 43	F; p L; R; v g l b M; 30…40″; has a ✻ 8.9 m, dist 5′; pos 75°±	186
28	Nova.	0 23 31·7	27 39 17	A loose cl; ✻s 11 and 12 m; 10′ diam; place that of a double ✻ (h 1033) whose Æ is erroneously stated in my 4th Catalogue.	219
29	Nova.	0 23 53·3	42 26 30	v F; v L; irr R; 4…5′ diam; loses itself insensibly; has a ✻ 11 m in centre.	207
30	II. 478	0 25 26·2	100 38 31	v F; p L; E; v g l b M; 60″	310
31	III. 467	0 25 43·0	103 35 56	e F; S; R; 15 or 16″	373
32	III. 476	0 27 8·6	66 58 46	Has a ✻ 7 m, 5′ dist; pos of neb from ✻ 195°·5	166
33	III. 871	0 28 28·6 :	88 57 23 : :	e F; a doubtful observation	112
		29·2	59 59	v F; R; b M; 20″. A star 11 m pos 225° ±, dist = 80″	113
34	Nova.	0 29 13·5	5 36 24	Cl v L p Rich 150…200 st 10…18 m; more than fills the field	381
35	II. 707	0 29 33·1	42 35 56	p B; L; R; g b M; full 60″ diam.	390
36	Nova.	0 29 58·5	29 52 27	Cl L; p rich; irreg R; 8′ diam; straggling; ✻s 11…15 m	219
37	Nova.	0 30 17±	87 35 0 :	v F; L; close to a ✻ 15 m. Æ by III. 595, which this precedes 25ˢ·5.	95
38	II. 479	0 30 22·2	99 56 21	v F; R; sky rather dull	310
39	III. 872	0 30 29·2	90 4 37	p F; p s b M; 25″	113
		29·2 :	4 5	The s p of two, and probably a third. Cloudy	112
		29·3	4 45	p B; p m E; b M; 40″1.	371
		30·1	3 49	F; R; b M; (, but certainly seen	108
		32·8	4 42	F; p L; R; b M.	110
40	II. 856	0 30 33·2	87 52 50	p B; S; R; b M.	95
41	II. 860	0 30 33·8	90 1 50	p B; R; b M; 30″	371
		34·2	1 49	F; R; p s m b M; 30″	113
		35·1	0 9	F; (, but certainly seen; a stellar centre	108
		35·2	1 28	v F; R; 1 b M; 40″; the n f of 2; hazy	112
42	III. 595	0 30 42±	87 37 ±	p B; R; the f of 2. Δ Æ = 25ˢ·5; Δ P D = 2′	95

No.	Synonym.	Æ 1830·0. h m s	N.P.D. 1830·0. ° ′ ″	Description and Remarks.	Sweep.
43	III. 873	0 30 47·7	90 4 37	v F; L; E; 60″. The last of 3 on the parallel of the first ..	113
		50·7	5 30	v F; E; v g l b M; 60″	371
44	V. 18	0 31 8·1	49 14 45	p B; v L; m E; pos 160...170°; 15′ l; 7′ br; a faint suspicion of a nucleus; ☾.	183
45	V. 36	0 31 10·7	50 11 30	A very large space filled with neb	180
46	II. 452	0 32 1·2	104 48 51	B; R; p s b M; 25″	307
		1·5	48 21	B; R; p g b M	373
		2·7	47 32	p B; R; p s b M; (a thick haze)	308
47	II. 209	0 32 30·4	65 25 47	p B; R; g b M; 25″	172
		...	26 15	p F; R; g b M; 20″	392
48	II. 480	0 32 59·2	100 56 56	not v F; S; g b M; 10..15″	310
49	III. 244	0 32 59·2	111 58 54	e F; l E, n f to s p	293
50	M. 31	0 33 26·3	49 39 40	The great nebula in Andromeda	180
51	M. 32	0 33 27·8	50 4 7	The companion of the great nebula. e B; p L; s b M to a * 10 m; 40″; a small star follows it 11″·5.	183
		.....	.....	Viewed. v B R; p s b M; 30″; a * 13 m follows 11″·0	180
52	VIII. 78	0 33 35·5	29 8 37	A fine L, loose cl; stars 9.10 m on a dark ground; no small stars. Place that of a D (h 1046).	219
53	Nova.	0 33 47·9	58 20 49	e F; S; R; has a * 13 m to s, dist 20″	106
54	III. 146	0 34 29·2	60 20 26	not v F; R; b M; 15″	177
		29·4	21 17	F; R; l b M; 30″; ☾☾, yet distinctly seen	114
55	III. 485	0 37 14·9	106 30 51	v F; S; R; has * 10 m 3′ s	307
56	V. 25	0 38 30·5	102 48 36	v F; diffused neb involving stars	373
		31·2	47 57	A small constellation in a v diffused neb	308
57	V. 20	0 38 44·8	111 40 49	e F; v L; v m E; v g l b M; 10′ l; pos 172°·0. Has no B * in it, but a * 8.9 m at some dist n p.	293
58	III. 204	0 38 54±	71 19 40	v F; R; follows a * 6.7 m 40ˢ and is 1½′ n of it. It is near 2 v s st. If this be III. 204, my father's P D is 5′ wrong Æ by working list.	312
59	II. 609	0 38 55·4	63 18 17	F; R; b M. A coarse D * precedes	114
		57·5	18 5	p B; R; s b M; 15″	178
		57·6:	18 35:	v F; R; b M; 15″	392
		57·7	18 51	p B; R; p s b M; 20″	172
60	II. 611?	0 39 3·4	63 18 6	Not v F; R; b M; 15″. Query if not the same as II. 609	177
61	V. 1	0 39 11·7	116 12 55	A v L, m E, v B neb. (See figure 52.) Observed also in sweep 292, but no place taken.	306
62	II. 472	0 39 12·9	102 24 31	v F; L; R; g b M; 30″	373
63	Nova.	0 39 24·0	93 47 14	e F, (through fog.) Makes obtuse-angled triangle with 2 st ..	97
64	II. 621	0 39 24·4	93 42 32	F; E; 30″ l; barely seen through fog	96
65	III. 153	0 40 36·2	58 39 26	F; S; R; b M; has a * 8 m nearly s, 4 or 5′ dist	104
		36·4	39 12	p B; p L; R; p s b M; has * 9 m, s f, dist 3′	100
		37·0	38 59	p B; E; b M; has * 7 m 3ˢ·5 f, 4′ s	106
		37·6	39 20	p B; S; R; b M; a * 8 m to s, dist 5′	102

Fig. 52.

No.	Synonym.	$\mathcal{R}$ 1830·0. h m s	N.P.D. 1830·0. ° ′ ″	Description and Remarks.	Sweep.
66	III. 463	0 41 28·8	96 7 37	Very doubtful; (	40
		31·1	8 3	No description	186
67	II. 446	0 42 2·5	92 49 50	Not v F; R; p s l b M; 30″; a * 8·9 m follows rather to s Δ $\mathcal{R}$ = 5ˢ·5.	371
68	III. 955	0 42 7±	99 35 1	F; S; R. $\mathcal{R}$ from my father's obs	310
		.....	36 0	v F; R; p g b M	315
69	III. 429	0 42 25·7	97 58 53	A fine double neb; the preceding only seen by my father. p B; S; s m b M. The f is v F; S; R; pos = 60° (30° n f); dist of centres 40″. The neb join at borders.	186
70	Nova.	0 42 28·0	97 59 13		
		.....	.....	The prec p B; the foll v F. They form a double nebula, which is described by my father only as an extended single one.	187
		.....	.....		
71	I. 159	0 42 29·6	43 22 6	B; S; R; v g l b M; 20″. Approaching to planetary; makes a v obtuse-angled triangle with 2 st 10 m.	390
72	III. 477	0 43 24·6	66 34 36	e F; R; has a * 15 m f dist = 30″	166
		...	35 51 : :	e F; S; has a * near	172
73	III. 439	0 43 27·4	93 9 5	v F; S; R; b M; seen, but hardly discernible	96
		28·0	8 56	Not e F; S; R; g b M	97
74	VI. 20	0 43 50·7	117 30 30	(nisi $\mathcal{R}$ = 44ᵐ 25ˢ·7.) A fine rich, not v comp L cluster	292
75	Nova.	0 44 14·9	58 26 49	e F; S; R. The faintest object imaginable; (night wonderfully clear.)	106
76	Nova.	0 47 25·7	78 50 39	A small cluster of p closely scattered stars	15
77	Nova.	0 47 53·2	92 41 15	p F; S; E; 15″	371
78	Nova.	0 48 18·3	60 38 30	p B; R; g b M; 10″	178
		18·8	37 46	F; v S; R; b M; 6″	177
79	II. 210	0 48 33·4	60 34 57	p B; R; g b M; has * 9 m 45° s f, dist. 3′	114
		34·3	33 45	B; R; p s b M; 20″	178
		35·3	33 54	B; p L; g b M; 25″	177
80	II. 433	0 51 15·3	98 29 36	F; L; E; 50″. Sky not very clear	186
		15·4	29 36	Not v F; L; E; g l b M; has * 10 m 20ˢ·5 f in the parallel.	187
81	III. 191	0 53 32·0	95 9 41	v F; S	96
		35·9	9 26	Precedes by 1ᵐ 37ˢ a star 8.9 m; a * 10 m between	97
82	II. 434	0 54 45·4	97 15 35	F; R; s b M, to * 13 m; 20″; a * 14 m 10° n f 20″ dist	187
		...	15 2	F; S; r	40
		...	16 ±	p B; R; 20″; hazy	186
83	Nova.	0 55 54·8	28 43 47	A small cl 2′ in diam. Place that of the D * h 1070 whose $\mathcal{R}$ in my 4th Catal is 2ᵐ wrong.	219
84	II. 215	0 57 52·6	58 23 50	p B; R	100
		54·0	23 55	p B; not v S; b M	106
		54·2	23 46	F; R	104
85	II. 216	0 57 54·6	58 27 ±	p B; R	100
		56·0	25 55	p B; S; s b M	106
		56·2	26 11	F; p L; R; b M	104

No.	Synonym.	Æ 1830·0. h m s	N.P.D. 1830·0. ° ′ ″	Description and Remarks.	Sweep.
86	II. 217	0 58 0·2	58 30 ±	F; R; b M; 5 or 6′ s of II. 216	104
		1·6	32 ±	p B; R. P D requires an uncertain correction, being taken much out of the meridian.	100
		3·5	29 55	p B; p L; g b M	106
87	II. 218	0 59 0·6	57 46 50	p F; b M nearly to a ✱; between 2 stars	102
88	I. 54	0 59 0·6	51 15 8	F; S; R; s b M. It is bright 3^{d} or F 2^{d} class (sky perfectly clear), and = ✱ 14 m. One of a group of 5 or 6 st 15 m.	188
		4·6	15 3	v F; v S; l E; g b M; 10″. Allowing for the ☾ &c. this cannot be a 1^{st} class neb; no other near it.	183
89	II. 224	0 59 58·9	55 12 6	B; R; g b M; 30″	105
		59·5	11 41	p B; R; p g b M; 30″	168
90	III. 154	1 2 46·6	58 46 50	p B; S; R; b M	102
91	III. 592	1 4 9·2	91 12 44	v F; R; s b M	113
92	III. 593	1 4 14·4:	91 13 59::	No desc. Place estim from II. 447	113
93	II. 447	1 4 19·7	91 8 59	F; R; v s b M to a ✱	113
94	Nova.	1 4 35·6	30 46 28	A star 8 m the chief of a small loose cluster	213
95	Nova.	1 4 36·4	57 11 26	F; S; v s b M	106
96	Nova.	1 6 50·1	59 52 16	v F; E; a ✱ 9 m n p and a S ✱ n f at the extremity of the nebula	106
97	VII. 42	1 8 33·1	32 34 8	a D ✱ 10 m, pos 324°·5, dist 12″, in the midst of a p rich L cl which fills the field. The stars are 10 m; one of 7 and 1 of 8 m in the s f part.	213
98	Nova.	1 10 22·8	58 11 27	v F; e S; stellar	106
99	III. 250	1 10 23·9	87 34 48	No description	95
100	III. 577	1 11 37·1	50 23 49	e F; S; R; v g l b M; 15″; ☾	183
101	Nova.	1 12 13·7	83 52 32	e F; p L; R; has a red ✱ 7.8 m 45° s p	118
102	III. 156	1 12 25·5	57 27 ±	v F; so that I had difficulty in finding it again when it had quitted the field.	100
103	III. 252	1 12 57·7	85 37 58	p B; L; R; b M; 30″	95
		58·2	37 51	B; L; s v m b M, and losing itself imperceptibly; r in centre with 320; ✱ 7 m in parallel 1^{m} f.	300
104	Nova.	1 13 23·8	57 42 47	v F; E; has a D ✱ to s	106
105	III. 594	1 13 27·2	89 56 36	v F; L; E; pos by diag 60°·0 ±; l b M; 90″ l	113
106	III. 158	1 13 38·5	57 26 20	p B; p L; R; through fog	102
		39·5	26 9	p B; R; b M. N.B. nebulæ numerous hereabouts	100
107	Nova.	1 13 56±	57 46 ±	It precedes III. 159 by about 10ˢ, and is half a field to the south of it	106
108	III. 159	1 14 6·1	57 38 17	p B; p L; b M	106
		8·7	37 56	e F; R	104
109	III. 160	1 14 8·4	57 36 21	v F; pos from III. 159 = 15°·0; dist = 2′ ±	106
110	Nova.	1 14 26·9	56 59 21	v F; v S	105
111	III. 169	1 14 53·5	57 5 56	F; S	105
112	II. 252	1 14 58·4	77 59 19	v L; irr R; v g l b M; by diagram at least 3′ in diameter; a remarkable object. Is closely followed by the D ✱ h 13; see fig 38.	15
		63·0	57 57	e F; L; R; 60″; has a ✱ 9 m 20° s f, dist 100″. (N.B. This place and the former description to be preferred.)	173

Fig. 38.

No.	Synonym.	R 1830·0.	N.P.D. 1830·0.	Description and Remarks.	Sweep.
		h m s	° ′ ″		
113	III. 167	1 15 4·5:	57 26 5:	Precedes III. 168, and is 2′ north	102
114	III. 168	1 15 8·0:	57 28 5	p B; R	102
115	II. 461	1 15 43·4	89 9 52	B; p L; R; b M	110
		51·7	9 44	v F; R; b M. This or the R of sweep 110 mistaken 10ˢ	113
116	III. 253	1 15 46·5	87 4 43	p B; E like a comet, pos 135°·0 ±; 60″·1	95
117	I. 151	1 15 52·5	81 21 17	v B; p L; R; p s m b M; 60″; 4 st near	118
118	Nova.	1 16 3·2:	56 10 58:	p B; v S; s b M. The preceding of two	105
119	III. 556	1 16 25±	81 38 57	Not v F; L; R; b M. 40″. R brought up from my father's obs not having been taken.	118
120	III. 171	1 16 43·2	56 11 28	p B; p L; g b M; the following of two	105
121	II. 462	1 16 46·4	89 7 33	Barely, but certainly seen; (	108
		47·8	7 30	B; p L; R; b M	110
122	II. 463	1 17 59·2	88 52 9	p F; R; p s b M; 30″	113
		62±	52 27	p B; S; E from p to f; b M; "has a granulated" (i. e. a resolvable) "appearance".	110
123	III. 560	1 18 0·4	53 41 53	v F; E; v g l b M; near a * 13 m	188
124	Nova.	1 18 12·2	28 35 19	A fine rich cluster 5′ diam; irreg fig; (windy)	216
125	Nova.	1 19 29·1	58 33 21	v F; S; R	106
126	Σ. 131	1 21 58·9	30 11 18	A fine cl; R; rich; rather coarse; 6 or 8′ diam; stars 10 ... 11 m. One of Struve's "acervi".	213
		65·7	11 42	The chief * in a cl VI or VII class 8′ diam, which has one v red * near the middle; stars 9 ... 12 m.	219
127	Nova.	1 22 6·1	57 15 53	v F; p L; g b M	106
128	I. 100	1 22 48·4	97 44 18	B; R; p g m b M; 15 ... 20″	318
		48·5	45 13	B; R; g m b M; 60 ... 90″; between clouds and in thick haze. Must be v B in clear weather.	39
		48·6	44 48	v B; R; p s b M; 25″. (Seen also sw 40, but no determination of the place obtained).	186
129	Nova.	1 23 1·6	91 48 7	v F; R; b M; 25″	113
130	III. 431	1 23 5·5	97 46 8	v F; R; 15″	318
131	V. 17) M. 33)	1 24 15·6	60 13 9	Enormously L; v g b M. The nucl taken; has * 12 m, n f the nucl. The diffused neb extends 15′ s and as much nearly to n. It has irregularities of light, and even feeble subordinate nuclei and many small stars. Probably V. 17 is part of the diff neb of M 33.	177
132	II. 4	1 24 23·9	97 53 32	p B; R; a * 6 m follows 47ˢ·5 and is 40″ n	40
133	III. 150	1 24 36·2	60 7 6	v S; almost uniformly B. Place by rough comparison with the nucl of M 33, with which its pos = 51°·1 Δ P D = 6′ 3″ ±.	177
134	Nova.	1 25 41·6	57 13 29	v F; p s b M. Stellar	106
135	III. 174	1 26 11·1	57 11 34	p F; p s b M. Stellar, or like a star blurred	106
136	Nova.	1 26 37·5	57 28 43	p B; p L; b M; precedes a * 2ᵐ 51ˢ·0	102
137	II. 282	1 26 48±	98 12 0:	p B; R; is s f a * 8 m distant 10′	186
138	III. 454	1 27 16·7	90 12 22	v F; not v S; not b M	110
		...	11 ±	The faintest thing imaginable	113

No.	Synonym.	Æ 1850·0. h m s	N.P.D. 1850·0. ° ′ ″	Description and Remarks.	Sweep.
139	I. 281	1 27 22·9	120 21 53	v F; R; l b M; 20″. This is probably Mr. Dunlop's No. 479, but one or the other Æ requires correction.	292
140	III. 471	1 27 26·1	100 52 50	e F; S; among 2 or 3 v F st very difficult	315
141	Nova.	1 27 27±	57 17 ±	v F; R; another precedes, which must be III. 174. The Æ conjectural, and P D liable to some error.	100
142	M. 74	1 27 34·8	75 4 46	e F; 5′ with a brighter mass = 1′ in centre, and this again p s b M to a suspected *. Several v s st near.	319
		34·8	5 17	B; L; R; p g m b M; 90″ diam; resolvable	173
143	Nova.	1 28 26·0	84 59 29	p B; S; R; p s b M; 15″	300
144	II. 283	1 30 36·9	98 22 33	F; v S; R; v g b M; 10″	318
		38·6	22 18	p F; S; R; p s b M; 20″	186
145	VII. 46	1 32 25·9	28 58 17	A cluster of the 6th class, (i. e. very rich)	219
		26·3	58 44	A fine rich cl; st 11....14 m; 3′ diam; irreg fig; place that of the most comp part; one star 6.7 m, s f the centre, is ruddy.	216
146	Nova.	1 32 45·9	34 59 2	A D * (h 2070), the chief of a p rich loose cl; st 12 m.	386
147	II. 610	1 34 42·8	62 9 6	p F; S; R; p s b M	177
		...	10 ±	F; v S; R	181
148	Nova.	1 34 57·6	86 37 45	v F; R; 20″	300
149	II. 611	1 37 51·3	62 58 15	v F; R; 15″	392
		53·0	57 51	not v F; S; E nearly in Mer; 15″ C; 10″ br	177
150	I. 157	1 38 19·4	63 25 20	Between two stars	181
		20·6	25 40	e F; l E; sky not perfectly clear. Taken while looking for Encke's comet.	392
		...	25 30:	p F; E; v g l b M; pos n f to s p; between two stars; 6′ l; 3 or 4′ br	178
151	IV. 42	1 40 4·0	84 56 15	A * 9 m with a v F neb ray. A * 17 m p	95
		4·2	56 16	A * 9 m with a v F narrow ray of neb; a most curious object. See fig 58.	300
152	II. 612	1 40 22±	63 12 35	v F; R; near a * 15 m. Æ per working list	392
153	Nova.	1 40 42±	79 9 19	e F; Æ may be a whole minute wrong	15
154	II. 501	1 40 51·0	105 48 56	v F; R; v g b M; 15″	307
155	III. 459	1 40 57·7	114 38 19::	v F; R; g b M; 15″ a * 8 m, s p. (N.B. Both this P D and that of sw 292 are open to much error.)	306
		59·4	40 37::	v F; R; makes obtuse triangle with 2 st 8 and 9 m nearly in merid and 6′ asunder.	292
156	II. 859	1 41 37·0	84 42 7	p B; E; v g b M; a * 10 m, n f.	300
157	III. 562	1 42 42·4	54 40 58	v F; the n p of two, dist 90″ ±	105
158	III. 192	1 42 45·0	94 53 48	e F; 90″ n of a * 11.12 m	96
		47·6	53 38	e F; l E in Mer; has * 14 m 90″ s	97
		...	54 24	e F; R; the transit missed	39
159	III. 563	1 42 49·4	54 42 1	p B; p L; l b M; 40″	105
160	I. 62	1 42 54±	100 32 56	v F; R; v g v l b M. Aurora in sky even so far south, strong enough to illuminate the field of view and render the wires visible without a lamp.	310
161	II. 596	1 42 56·8	84 33 17	p B; 30″; a * 13 m 1 radius of neb dist from edge	300

Fig. 58.

No.	Synonym.	R 1830·0.	N.P.D. 1830·0.	Description and Remarks.	Sweep.
		h m s	° ′ ″		
162	55 Androm.	1 43 8·6	50 6 40	55 Androm. A fine nebulous * with a strong atmosphere losing itself imperceptibly; diam 90″. It is also a double * h 1094; called "nebulosa" by PIAZZI.	183
163	Nova.	1 43 10·9	54 1 18	v F; R; among several p B stars	188
164	II. 270	1 44 22·9	86 38 10	p B; R; p s m b M; 30″	95
		24·4	38 32	B; R; p s b M; 25″	300
165	I. 105	1 44 44·7	104 34 27	v B; E; p s p m b M; 40″ l; 30″ br.	308
166	III. 460	1 45 49·8	114 35 22:	not v F; R; v g b M; 30″; has a * 13 m 90″, s	306
167	Nova.	1 45 50·7	114 42 17:	v F; p L; R; g b M; has a small * 75°·s p. It is *barely possible* that this may be III. 460 with a mistake in reading the P D.	292
168	Nova.	1 46 14·6	86 38 10	A suspected nebula.	95
169	II. 221	1 46 49·9	57 48 1	p B; has a S * or stellar neb to the n	106
		50·1	47 38	p B; R; b M; has * 13 m n p	100
		50·1	47 45	F; R; has a * near it	102
170	Nova.	1 47 2·5	30 39 43	A D * in the f part of a L, poor, triangular cl of 15 or 20 st 10 ... 13 m.	213
171	Nova.	1 47 9·0	35 22 7	p rich, irreg fig^{d} cluster of *s 11 ... 13 m 8′ diam	386
172	II. 271	1 47 29·0	85 12 23	The prec and brightest of a fine double nebula; p F; R; p s b M; 20″; pos of the other = 102°·4.	300
173	II. 272	1 47 29·4	85 12 35	The f and fainter of a double neb; v F; R; s b M; 12″	95
174	VII. 32	1 47 39·6	53 10 8	An enormously L, p rich, sc cluster. Place that of a conspicuous *. The densest part is 10′ n.	188
175	II. 222	1 47 43·6	57 38 35	p L; E; precedes a p B * by 18ˢ·0	102
		...	40 ±	p B; R; R not taken; P D rough	100
176	III. 193	1 47 48·9	95 18 9	e F; is 45° s f a * 9 m; Δ R = 6ˢ·0	96
		51·0	18 5	e F; 45° s f a *; Δ R = 6ˢ·25	97
177	III. 265	1 48 10±	99 51 56:	F; S; R. Transit missed; P D imperfect.	310
178	III. 464	1 48 25·6	96 14 0	e F	39
		26·1	14 18	F; l E; v g b M	318
179	50 Cassiop.	1 49 6·2	18 24 27	I suspect this star to be nebulous	378
180	Nova.	1 49 43·1	82 29 4	v F; S; R; 15 ... 20″; a * 10 m 15° n p; 2′ dist	118
181	I. 112	1 49 59·5	71 49 6	p B; R; g b M; 40″	319
		61·6	49 0	L; R; through thick cloud. Obs so doubtful that but for the agreement of the transits over both wires I should not have believed I saw it.	312
182	II. 233	1 50 26·5	59 23 53	B; R; g b M; 40″; a considerable neb.	106
183	I. 101	1 51 8·6	96 47 47	B; E; b M	39
		11·2	46 28:	p B; p L; E; pos about 160° by diag	40
		11·9	47 28	p B; m E; pos = 163°·0; b M to nucleus	318
184	III. 583	1 51 10·1	62 35 18	e F; 3 st in Mer precede it; the largest 10 m is 20° s p the neb	177
185	II. 435	1 52 43±	97 39 10	B; p L; R; b M. Transit missed; R by working list. Also observed sw 40, but no descrip, and place only roughly set down.	39
186	III. 433	1 52 50·4	96 11 53	F; p L; R; b M; 25″	318
		...	13 +	No descrip; taken much past merid	39

No.	Synonym.	R 1830·0. h m s	N.P.D. 1830·0. ° ′ ″	Description and Remarks.	Sweep.
187	Nova.	1 53 2·0	75 6 22	e F; S; R; has a * 11 m 15° n f	173
188	III. 207	1 53 10·8	72 26 41	F; S; R; g l b M; 12″	319
189	III. 566	1 53 21·4	52 42 38	v F; R; s b M; near a *	188
190	III. 208	1 54 31·1	74 46 46	v F; not v S; g l b M; follows * 10 m 3ˢ·5	319
191	III. 151	1 55 12·1	61 49 31	v F; v S; 6″; has * 12 m, 1′ n, and another about 20° s p	177
192	Nova.	1 56 3·7	114 6 42	v F; R; v g b M; 40″	306
193	I. 152	1 58 15·3	79 49 27	Not v B; R; s b M to nucl; has * 10 m s p, dist 55″. P D by obs 78, but no doubt should be 79.	121
194	II. 604	1 58 30·9	52 3 1	p B; E	188
195	Nova.	1 59 12·5	76 27 37	F; R; b M; 15″	173
196	Nova.	1 59 34·5	116 15 37	A v F double * inclosed in a v F neb	306
197	II. 605	1 59 51·8	51 37 31	p B; R; g b M; 25″; has a D * 15ᵉ foll	188
198	III. 227	1 59 59·2	82 50 22	v F; R; b M; 20″	118
199	II. 482	2 1 1·6	100 56 10	v S; R; the first of a group of 4	315
		1 1·7	56 21	F; S; R; the first of 4 in a crooked line	310
200	II. 483	2 1 4·6	100 56 25	The 2nd of 4. It makes a double neb with the first.	315
		5·2	56 31	F; S; R; the second of 4 in a crooked line	310
201	II. 484	2 1 19·5	100 57 6	F; S; R; the third of 4	310
		19·6	57 0:	The third in order and in size	315
202	II. 485	2 1 23·5	100 59 56	F; S; R; the last and largest of 4	310
		...	60 ±	Seen. Place estimated by the others	315
203	Nova.	2 1 25·9	98 33 43	v F; R; p s b M; 12″	318
204	III. 604	2 2 8·9	53 19 30	v F; irreg fig	188
205	III. 260	2 5 52·7	91 33 11	v F; R; b M	108
206	III. 457	2 6 32·2	84 48 1	e F; R; attached to and n p a * 11.12 m. Clouded before it could be fully verified.	300
207	VI. 33	2 7 8·2	33 37 3	The splendid cl in Perseus. A most noble group. Much more than fills field. 2 st 7 m, the rest 8...14; one of 7 m taken, at the circumf of an ellipse of stars.	213
		12·4	39 42	v superb cl. Has 2 st 8m, the rest 11...13. Fills the field and has many stragglers. In centre is the D * h 1114 and an ellipse of stars.	387
208	III. 201	2 7 55·5	76 14 19	v F; E; has a * 10 m 4′ s f	173
209	II. 474	2 8 14·2	102 8 57	F; R; fog thick. (N.B. The obs makes P D 104°, which must be a mistake.)	308
		16·7	8 1	p F; p L; R; v g b M; 60″; by a strange conflict of errors *this* obs makes the P D 101°. Both are obviously wrong.	310
210	II. 246	2 8 45·0	76 14 37	p B; R; p g b M; a small * s f; dist 1′ and a * 9 m 5′ dist nearly s, a little foll.	173
211	II. 436	2 9 45·1	97 25 49	e F; b M; hardly visible (cloudy)	39
212	VI. 34	2 10 0·7	33 37 13	A noble cluster which just fills the field. It is the following of the two great clusters in Perseus; loose, but more condensed in middle. The borders graduate away.	213
		28·6	41 12	A fine cl; v L; the foll of two clusters which are quite separate. A fine ruby * in the centre.	387

No.	Synonym.	R 1830·0.	N.P.D. 1830·0.	Description and Remarks.	Sweep.
		h m s	° ′ ″		
213	Nova.	2 10 21·1	74 57 21	e F; R; g b M; 12″; near a * 16 m	319
214	Nova.	2 10 30·5	27 0 42	A coarse straggling cl; not v rich; 10 or 12′ diam. Stars 9 ... 13	221
215	II. 487	2 10 37·9	97 34 28	p B; R; g b M; 15″; a coarse D * in field	318
		40·9	33 46	F; R; b M	40
216	III. 486	2 11 28·7	106 50 26	p B; R; p g b M; 25″	307
217	II. 225	2 11 53·0	57 31 40	p B; R; b M; 25″; bad fog	102
		54·7	31 6	B; R; p s b M	106
		55·2	30 54	p B (in spite of a fog); R; b M; 3 small st in a curve to s p	104
		56·5	30 57	p B; R; g b M; has 3 or 4 S st p in a curve	100
218	V. 19	2 11 58·3	48 25 8	An extr F ray 3′ or 4′ l; 40″ br. Pos with mer = 23°·5 bad meas, the neb being too F to illuminate the wires.	389
Fig 28.		...	30 ±	Place hardly more than conjectural, being too late to get it on merid; v L; v m E; p F; has a chink or dark division in the middle and two stars. Pos with merid 21°·2. A wonderful object. See fig 28.	182
219	II. 438	2 13 5·9	96 18 28	v F; v L; R; v g l b M; 90″	318
		...	20 ±	F; v L; b M; viewed much out of meridian	39
220	Nova.	2 16 4·3	58 31 48	v F; S; R; forms a semicircle with 4 st	106
221	Nova.	2 16 9·8	72 16 1	p F; L; R; 60″; n p a * 10 m dist, 3′	319
222	III. 177	2 17 8·2	57 11 46	v F; E; two st 13 m n p near	104
		9·1	11 31	p B; L; E; v g b M; among stars	100
223	IV. 23	2 18 57·6	91 54 29	v B; v L; R; p s m b M; 2′ diam; fades away insensibly	108
224	III. 261	2 19 50·0	91 55 46 : :	v F; L; R	108
225	II. 487	2 20 18·9	101 18 25	v F; cloudy. Doubtful obs	315
226	I. 154	2 20 29·0	53 37 59	B; E in merid; g b M; 30″ long	188
227	Nova.	2 21 20·3	33 13 52	A p rich, p L, cl; st 13 ... 15 m; not comp at the centre. Fig an irregular parallelogram.	387
228	Nova.	2 21 32·4	46 7 43	p rich cl; 2 or 3 B and about 20 st 13 ... 15 m; a star 9 m taken	389
229	II. 278	2 21 53·1	91 51 16	p B; S; E; b M	108
		...	51 ±	p B; S; E; p s b M	113
230	II. 237	2 22 8·1	93 42 2	p B; R; or irreg fig; b M	96
231	Nova.	2 23 56·8	57 48 47	S; R; p s b M. The first of 3	106
232	II. 211	2 24 2±	61 25 ±	p B; l E; p g b M. R from working list; P D uncertain	178
233	Nova.	2 24 13·3	57 48 17 :	v F; R; b M. The second of 3	106
234	Nova.	2 24 33·8 :	57 54 25 : :	p B; R. Place by rough comparison with the first of the three	106
235	III. 572	2 24 40·5 :	49 55 25 :	v F; S; the preceding of two. Dist 3′; pos from the next = 337°·0.	182
236	III. 573	2 24 44·8	49 52 39	p F; S; l E	182
237	III. 161	2 26 33·8	57 25 11	v F; R; S; b M; 2 st 14 m n p point to it	104
		36·6	25 20	p F; R; S; p s b M	100
238	III. 557	2 27 6·8	79 6 32	p B; R; p s b M; 25″; ☾	121
239	III. 434	2 27 17·3	97 54 28	e F	318

No.	Synonym.	Æ 1830·0.	N.P.D. 1830·0.	Description and Remarks.	Sweep.
		h m s	° ′ ″		
240	II. 238	2 28 32·1	49 51 49	p F; p L; l E	182
241	III. 152	2 29 10·4 :	60 35 40	p B; irreg R; b M; 18″; r. Æ doubtful	178
242	I. 156	2 29 46·4	51 40 39	v B; v m E; v s m b M, to a ✱. Lenticular; 5′ long; pos by diagram 20° n f to s p. See fig 56.	188
243	II. 592	2 30 1·8	79 53 40	F; R; b M; 20″; has ✱ 11 m 40° n f; 25″ dist	121
244	I. 102	2 30 4·3	97 25 40 : :	p b; p L; irreg R; 2′ diam; r	38
		7·2	25 33	No description	39
		9·5	24 23 :	No description	40
245	III. 581	2 30 22·2 : :	72 42 1 : :	Doubtful obs. Clouded	319
246	II. 5	2 30 37·3	89 37 46	p F; R; b M; forms a trapezium with 3 st	108
		41·2	38 49	B; R; S; l E; forms a trapez &c.	113
247	III. 475	2 31 1±	71 27 30	F; R; l b M; 15″. Æ by working list	314
248	M. 34	2 31 6·1	47 56 43	Fine cluster; about 20 st 9 10 ... 11 m and as many less. Fills field, coarsely scattered. Place that of a D (h 1123).	389
		8·7	57 50	Poor; coarse; very badly seen through haze	190
249	II. 284	2 31 7·4	98 52 13	p B; m E; has a ✱ 17 m at the s f end	318
		...	52 36	No description	310
250	Nova. Polarissima.	2 32 0	0 5 10	v F; R; g b M; 25″; has a ✱ 11 m 2′ s. This nebula is remarkable for its proximity to the pole. Owing to this the Æ cannot be determined exactly, and the P D is open to correction.	374
251	III. 228	2 32 0·5	81 59 57	v F; the p of two; a ✱ 10 m, p in same line	118
252	III. 229	2 32 8·0	82 1 12	e F; the f of two	118
253	II. 488	2 32 14·7	102 1 22	F; R; b M; 20″; fog	308
254	I. 63	2 32 41·3 :	98 59 36	B; irreg R; p g b M; r	310
		44·9	58 38	B; S; R; 20″; g b and p s m b M to ✱ 12 m	318
255	II. 633	2 32 48·9	53 24 9	p F; L; R; g l b M; 50″	188
256	III. 584	2 32 49·4 : :	62 9 5	p B; S; R; p s b M; 12″. Æ precarious	178
257	III. 162	2 33 0·7	58 17 41	p L; R; has a red ✱ 7.8 m 43ˢ·5 p; fog. A p good obs however in Æ.	104
		1·8	18 32	p B; p L; b M	106
		3·1 :	20 ±	F; S; R. (Place not to be depended on)	100
258	I. 1	2 33 2·4	90 16 36	F; L; E; a p B ✱ near	108
		3·6	17 29	F; p L; E 10° n f to s p; 2′ long	113
259	Nova.	2 33 4·4	72 43 15	e F; hardly sure	395
260	III. 163	2 33 35·7	58 15 22	v F; p L. The s p of two	106
261	Nova.	2 33 38·2	58 12 22 :	e F; S; the n f of two. Δ P D estim at 3′	106
262	M. 77	2 33 58·2	90 43 43	v B; not v L; R; p s b M; has ✱ 2′ dist 40° s f	108
263	II. 273	2 34 26·2	85 45 5	p B; R; g b M; 15″	95
264	I. 64	2 37 38·4	98 17 33	v B; L; E; 100″ l; 40″ br; v g l b M	318
265	II. 466	2 37 43·7	91 13 34	F; p L; b M	107
266	II. 465	2 37 49·3	90 56 46	e F	108
267	III. 462	2 38 46·6	90 58 36	e F; R; is pointed to by 2 st n a l p the neb	108

Fig. 56.

No.	Synonym.	Æ 1830·0.	N.P.D. 1830·0.	Description and Remarks.	Sweep.
		h m s	° ′ ″		
268	Nova.	2 40 43·8	49 2 39	Query whether a nebula or a knot of minute stars indistinctly seen.	182
269	III. 449	2 41 11·9	107 41 16	pB; pL; R; gbM; 40″	307
270	II. 601	2 41 48·8	48 29 54	vF; R; vgbM; 25″	182
271	II. 602	2 43 30·3	49 7 32	vF; R; vglbM; 30″	182
272	III. 450	2 43 44·9	107 20 21	vF; S; R; gbM; 15″	307
273	Nova.	2 44 13·1	91 58 54	eF; pL; gbM; has * 8 m f	107
274	III. 580	2 45 32·7	47 38 48	vF; vS; R; gbM; 10″; makes isosc triangle with 2 st 15 m	389
275	II. 470	2 46 19·7	100 43 26	pB; S; R; nearly stellar	310
276	II. 274	2 49 19·3	87 18 28	F; S; R; sbM; 12″	95
277	II. 239?	2 49 56·2	45 47 43	F; R; gbM; 20″; follows the D * h 2167, 6ᵐ·5	389
278	Nova.	2 50 54·1	48 5 59	eF; S; 5″	182
279	II. 620	2 52 7±	44 18 ±	vF; irreg fig. Suspected to be only a few stars. Æ from working list; P D approx.	390
280	II. 502	2 53 35·7	105 30 21	pB; pL; R; psbM; 40″	307
281	IV. 43	2 54 22·3	47 50 43	A star 14 m with some kind of faint nebulous appendage	389
282	II. 503	2 55 41·7	106 16 8	B; R; sbM; 40″	307
283	I. 109	2 56 45·6	116 42 53	B; R; psbM; 30″. My obs makes the P D 115°, but this must be a mistake, as my father has three observations agreeing in 116.	306
284	III. 578	2 57 25·4	52 16 29	F; vS; R; psbM; 12″	188
285	II. 285	2 57 57·3	100 12 5	pB; irreg R; psbM; 20″	315
		58·2	12 16	Not vF; S; R; vgvlbM	310
286	II. 504	2 58 6·2	106 15 44	vB; E; psbM; 30″ l; 20″ br	307
287	Nova.	2 59 19·1	37 18 57	A vS, close-packed group of 8 or 10 st 14 ... 15 m in a space of 30″ diam, so as easily to be taken for a p B nebula.	386
288	III. 262	3 2 59±	93 12 ±	Scarcely seen through thick haze. Æ per working list; P D approx	96
289	II. 286	3 2 58·7	99 34 35	eF; R; aB * 9 m n p	315
		60·2	34 41	pB; R; night hazy and bad	310
290	VI. 25	3 3 3·1	43 24 16	A rich, L, cl not v comp; irreg R with stragglers; stars 12 ... 15 m; brightest part 5′ diam. The middle taken.	390
291	III. 591	3 3 8·7	99 36 50	eF; vS	315
292	Nova.	3 4 18·8	95 52 21	F; S; lE; has a * 9 m 5′ dist nearly n	39
		19·3	51 50:	vF; S; E; bM; 15″ long	38
		23·3	51 39	F; R; bM	40
293	II. 603	3 8 34·6	49 6 49	pB; R; gbM; 40″	182
294	III. 574	3 10 25·8	49 18 22	eF; R; bM; the n p of 2. Pos from the following, which is the largest, 352°·4; dist = 100″.	182
295	III. 575	3 10 26·9	49 16 44	eF; bM; the n f of two	182
296	II. 287	3 11 43·3	96 52 0:	pB; bM; r; 60″	38
		46·4	52 53	vF; R; gbM; 12″	318
		47·8	53 19	vF; R; S	39
		48·3	52 11	F; R	40

No.	Synonym.	Æ 1830·0.	N.P.D. 1830·0.	Description and Remarks.	Sweep.
		h m s	° ′ ″		
297	III. 196	3 16 16±	93 37 ±	The northern of two in same merid	96
298	III. 197	3 16 16±	93 39 ±	The southern of two. Δ P D = 2½′	96
299	III. 445	3 16 33·8:	96 20 0::	e F; irreg fig; scarcely discernible	38
		37·4	21 18	v F; p m E; 20″ l, 12 br	318
300	III. 694	3 19 42·9::	18 0 23	No description	380
		47·4	0 52	F; R; g b M; 15″. Close to the D ✱ h 2190	378
301	VIII. 88	3 20 45·4	53 15 56	The chief ✱ (10 m) of a cl of about 60 st which fills the field of view.	188
302	III. 446?	3 25 14·8	95 39 48	v F; between a ✱ p and a D ✱ f	96
		15·6	39 31	No description. Clouded before obs could be completed	40
303	II. 288	3 28 36·1	95 35 40:	v F; L; R; 3′	38
		39·7	36 28	L; the faintest thing imaginable	96
304	III. 263	3 32 42±	91 50 ±	No desc. Æ from working list; P D approximate	107
305	III. 569	3 33 3·0	95 13 ±	No desc. The first of 3	96
306	II. 455	3 33 12·2	95 14 46:	R; n p a ✱. The second of 3	96
307	II. 456	3 33 31·7	95 17 ±	P D very doubtful	96
		33·0	15 33	p B; S; seen between clouds; has a B ✱ 1′ dist, 45° s f	39
		34·4:	15 46::	F; S	38
308	VIII. 80	3 36 36·1	37 52 0	A cl of about 20 st; place that of a superb D ✱ (Σ 446); the rest 12 m.	384
		38·5	52 7	A D ✱ Σ 446; the chief of a cl of 30 st more or less; 14…16m..	386
309	I. 155	3 38 2·7	94 30 22	e F; R; has a ✱ 17 m in middle	233
310	Nova.	3 51 30·9	37 50 57	A curious knot of stars forming a cluster in form the segment of an elliptic ring.	384
311	IV. 69	3 58 35·8	59 40 46	A ✱ 9 m with a dilute, F, equable nebulous atmosphere 60″ or 90″ diam. Other st 9 m have no such atm. A ✱ susp n p. See Fig 31.	56
		36·0	40 10	A ✱ 8 m with a fine atmosphere; diam 12ˢ of time; perfectly nebulous and fading away to nothing; a F ✱ following; strongly suspected to have a slight *chevelure*, but several 8 m near, not the least.	106
312	Nova.	4 9 47·0	53 30 21	The chief ✱ of a v loose poor cluster 30′ diam; 1 comp; stars 10…12 m.	399
313	III. 490	4 11 37·9	91 6 54	F; v S; a ✱ 11 m s p	110
		39·7	6 36	F; p L; v g b M	107
314	III. 587	4 17 54·6	94 1 12	e F; among small stars	233
315	I. 217	4 19 4·4	55 6 32	B; visible in full ☾ light; a ✱ 9 m dist 3′, 80° s p (afterwards corrected to n p. See Sw. 51).	42
		5·2	6 48	Place only taken. No descr. This obs makes the Æ 18 m, but this is an obvious mistake.	50
		5·4	6 21	p B; v L; irr R; it is inclosed among 6 stars, two of which point across its centre to a third. A ✱ 7·m precedes about 1 m.	105
		…	…	A ✱ 9 m is about 75° n p, not s p as in Sw. 42, and 2′ dist ..	51
316	II. 8	4 21 56·7	89 43 18	The s p of a double nebula; R; p L; distance of centres 60″..	107

No.	Synonym.	Æ 1830·0.	N.P.D. 1830·0.	Description and Remarks.	Sweep.
		h m s	° ′ ″		
317	II. 9	4 22 0·2	89 42 40	The n f of the double nebula; F; S; R. Pos by a drawing made at the time 30°..40° n f.	107
318	II. 7	4 22 0·9	89 31 14	p B; b M; E from s f to n p; has * 50° n f, 1′ dist; its situation is nearly at right angles to the longer axis of the nebula.	110
		...	30 ±	p F; R; p L; has a * 45° n f, dist 90″	107
319	I. 158	4 23 14·8:	95 26 0::	F; R; b M; 40″	38
		15·8	27 29	F; R; b M; cloudy	39
		16·4	27 22	p B; R; b M; 18...20″	233
		18·4	27 22	p B; R; g b M; 15″; sky perfectly clear	232
320	II. 524	4 27 36·8	93 30 28	No description; observation marked as doubtful	109
321	II. 514	4 27 52·2	90 29 39	v F; p L; irreg fig; 90″; has a coarse B double star n f	107
		56·0	26 ±	v F; L; m E; 3′ L; 90″ br; v l b M. P D merely estimated by means of a star near it.	110
322	Nova.	4 28 38·0	93 39 33	v F; E; 45° n t s f; s b M; follows ν Eridani 41ᵐ·0	109
323	III. 952	4 30 58·0	82 59 44	The n p of a double neb; F; has a * 8 m s p. Pos of the nebulæ about 65° s f by diagram.	119
		61·0	59 55	e F; p L; E towards the s f side, and has either a * or a second nucl s f.	118
324	III. 953	4 30 59·7	83 0 44:	The s f nebula of the double neb	119
325	II. 515	4 31 29·7	90 53 19	v F; R; has a * 9 m about 12ˢ·5 f to the n	107
326	II. 522	4 32 31·8	98 56 40	e F; R; v g b M; 30″	315
		...	56 58	No Æ observed; no description	318
327	I. 122	4 32 55·7	93 11 48	B; v L; R; b M; 2′ diam	109
		57·1	13 12	p F; L; nearly R; v g b M; 2′ diam	233
328	III. 588	4 35 23·1	95 39 14	e F; irr R; b M; 10″	232
329	II. 523	4 36 15·0	98 50 43	p F; R; has a * 7 m, 3 or 4′ dist n p	318
330	Nova.	4 37 32·3	95 27 44	e F; irreg fig, if not a double or triple star, seen indistinctly	232
331	III. 589	4 38 7·8	95 6 2	p F; v S; v l b M; 15″	233
332	VII. 1	4 39 5·6	79 22 40	A cluster of stars 11 and 12 m, three L and 5 small stars. Query if the right object.	121
333	II. 457	4 39 55·3	95 44 32	v F; p L; R	233
334	II. 527	4 44 1·8	93 23 50	p B; R; b M; has a * 7 m 45° s p; very well observed.	109
		2·9	24 2	p F; S; R; 12″; has a * 9 m dist 5′ s p	233
335	III. 453	4 45 33·6	88 38 55	e F; among v S stars; has one v L * s p	322
336	IV. 32	4 48 33·1	95 8 42	p B; R; like two or three stars 19 m with an atmosphere 60″ diameter.	233
337	Nova.	4 49 9·8	37 22 45	v Loose; p Rich; fills field; the largest * 10 m; mixed magnitudes	327
338	Nova.	4 49 38·0	82 1 34	A resolved nebula or a small round group of very small stars, 30″ diam.	118
339	Nova.	4 50 15·3	90 45 47	F; S; R; b M	110
		15·6	45 31	F; R; b M; the preceding of two.	107
340	Nova.	4 50 47 ±	90 31 ±	p B; R; p s b M; has a B * n f; the fol of 2	107
341	Nova.	4 51 30·4	98 1 3	F; R; about 30″ n of a * 13 m.	318
342	III. 503?	4 53 28·4	93 33 12	e F; S; 4″; has a * 12 m n f	233

No.	Synonym.	Æ 1830·0. h m s	N.P.D. 1830·0. ° ′ ″	Description and Remarks.	Sweep.
343	Nova?	4 54 16·1	94 58 20	A very large space affected with nebulous streams in zigzags up and down. (N.B. Such observations require several verifications. The opportunity has not occurred in this case.)	235
344	VIII. 61	4 56 34·5	52 50 56	A double ✱ in a pretty close cluster of 20 or 30 stars.....	399
345	III. 500	4 57 11·7	99 23 20	not v F; R; g p m b M; 25″.....	315
		13·4	22 53	p F; S; R	318
346	Nova.	4 57 50·9	38 9 40	A group of 8 or 9 stars 10 m, nearly in a parallelogram. A pretty object.	327
347	V. 32	4 58 24·0	93 34 22	A ✱ 10 m with a neb s f; pos 138·0 from ✱; the centre of the neb is like a misty ✱ 12 or 13 m, or perhaps 2 or 3 st 15 m; a small ✱ to the s of neb makes an isosceles triangle. Place that of the ✱ 10 m.	233
		28·2	36 45	B; L; R; p s b M; diam 3′; has a ✱ n p (about 45°) at the edge, if not involved.	235
348	Nova.	5 0 53·9	73 42 5	A cluster of 10 or 12 large and a good many small stars. The place that of a D ✱. It is perhaps an *outlier* of VII. 4.	395
349	VII. 4	5 2 11·6	73 28 5	L, rich cl; st 12...15 m; fills field. Place that of a D ✱. The most compressed part is 42″·5 foll the D ✱ and 3′ south of it.	395
		19·3	34 6	v L; p Rich; the prec border the brightest, consisting of st 10...12 m, but the foll the richest, consisting of st 12....18 m. Place of a ✱ 10 m in prec border.	396
350	VII. 33	5 8 21·9	50 50 36	A ✱ 7 m, very ruddy, almost orange-coloured, in a p rich cl of v s st.	399
351	Nova.	5 14 34·2	56 46 24	Rich coarse cl of sc st 9...15 m; more than fills field	51
352	II. 289	5 14 40·3	101 39 40	p B; R; r; 30″	315
353	VIII. 4	5 15 14±	61 0 ±	The most condensed part of a poor cl divided into two. It consists of 20 or 30 st 9....12 m.	115
354	VII. 39	5 16 41·0	54 50 36	Rich p comp cl s stars; roundish with straggling borders of larger stars.	51
		41·9	49 52	p Rich; irreg R; stars 9....12 m, 50 or 60 counted; b M; the place that of the most comp part.	42
		44·9	50 11	p Rich; scattered cl of ✱ s 12 m, and some larger, the most comp part = 3′ diam.	105
355	I. 261	5 20 7·9	55 53 54	A nebula including a triple star, forming an equilateral triangle; sides = 4″; stars = 11, 12, 14 m. See fig 49.	51 Fig. 49.
		11·3	53 22	A triple ✱ in a neb. A most curious object (see description of the d ✱ h 367 in my 2nd Catal.) The neb surrounds the stars like an atmosphere.	42
		13·9	53 41	A triple ✱ in a neb &c. &c.	105
356	V. 38	5 20 34·4	98 31 18	All about this place there exists diffused nebulosity.....	318
357	M. 1	5 24 15·7	68 6 36	v L; E; v g l b M; r; 4′ l, 3′ br; pos of longer axis n p to s f. A fine object. See fig. 81.	59
358	M. 36	5 24 56·5	55 57 52	A coarse straggling cl which fills the field; a v pretty object; place B ✱ in M.	42
		65·5	59 24	Rich; B; straggling stars; place of a D ✱ h 368 whose place in my 2nd Catal is set down very erroneously by a mistake of copying.	51
		70·4	59 16	A considerable rich cl of L st 9...11 m; fills the field. The chief ✱ is double.	105

No.	Synonym.	Æ 1830·0.	N.P.D. 1830·0.	Description and Remarks.	Sweep.
		h m s	° ′ ″		
359	III. 965	5 26 44·2	58 7 57	F; R; S; p s b M.....	106
360	θ Orionis	5 26 55±	95 30 30±	Observed in sweeps 16, 38, 40, 110, 172, 173, 232...235, 309, 318, &c. See description and figure in Mem. Astr. Soc. 1826.	....
361	V. 31	5 27 6·9	96 2 18	ι Orionis involved in a feeble neb 3′ diam	318
362	Nova.	5 27 7·4	94 28 10	A coarse and poor but v splendid cl of L st; a beautiful object	41
363	V. 34	5 27 35·3	91 19 3	σ Orionis. Place by Catal a v brilliant * involved in an immense nebulous atmosphere, whose n and s limits are 91° 7′ 29″ and 91° 31′ 29″. Viewed also and shown to Mr. Dunlop in sweep 110.	107
364	Nova.	5 29 42·5	34 17 57	A poor cl of 8 or 10 st 11 m	324
365	IV. 34	5 32 47·6	80 59 57	A circular disc 12″, a little mottled and of a pale light; a little ill-defined, but not hazy; a planetary nebula.	118
		48·3	60 19	Planetary neb a little indistinct at the edges; rather oval and perhaps of a mottled light.	121
366	VIII, 2	5 34 47·5	81 26 37	A large tract of stars filling many fields. It extends much further in Æ.	121
		...	18 ±	VIII. 2 viewed. A L ill-defined tract of loose stars, neither rich nor condensed.	118
367	Nova.	5 35 27·0	77 11 40	A * 8.9 m with F neb	393
368	M. 78	5 38 1·3	90 0 10	Two stars 9 = 9 m; pos 60° n f; dist 50″ in a wispy nebula. See fig 36.	113
		2·6	1 59	A v L wisp-shaped neb involving 3 st. It extends 5′; terminating abruptly to n, but extending s f beyond the 3rd *.	107
369	M. 37	5 41 8·2	57 30 56	v fine L cl, all resolved into st 10...13 m. It fills 1½ field, but the straggling stars extend very far. There may be 500 stars.	52
		10·3	29 54	Splendid cl st 11...15 m; no unresolved neb; p comp but not m b M; fills field.	51
		10·8	30 20	Irregular; not *very* rich; fills field	56
370	III. 510	5 44 32±	97 30 38	v F; R; p s b M. Æ from working list; P D approximate.....	318
371	VII. 24	5 45 4·7	89 39 29	The 2nd and brightest * of a poor straggling cl 10 or 12′ long	107
372	VIII. 26	5 50 45·2	66 42 40	About 40 or 50 st. The largest 8 m taken. The rest are 10...15 m	59
373	Nova?	5 53 50·8	100 36 25	3 Monocerotis. I am sure this star has a F neb atm 2′ or 3′ diam. Eye-glass examined, not dewed.	315
374	Nova.	5 54 2·8	84 16 53	L; p rich; very scattered; place of * 10 m in M.....	320
375	VI. 17	5 56 59·2	65 53 46	Rich; m compressed almost to nebulosity; stars very small; irreg triangular figure.	59
376	Nova.	5 57 36·5	38 17 51	A poor cl 7′ l, 3′ br; about a dozen st 11 m	325
377	M. 35	5 58 22·2	65 39 13	a L, coarse, p rich cl of st 9...16 m, which fills 2 or 3 fields, but chiefly one in which are about 100 stars.	58
378	IV. 44	5 58 40·9	96 11 43	A star 7 m with a p strong neb atmos.	318
379	VIII. 24	5 58 51·2	76 1 34	A pretty cluster of 20 or 30 st 10...11 m with one 9 or 9.10 which is double (Σ 848).	393
380	VIII. 6	6 0 36·5	85 15 48	A fine cluster; coarse; p rich; place of a * 9 m.....	320
381	IV. 38	6 1 13·9	96 18 48	The large star of a double star has a very strong nebulous burr	318
382	Nova.	6 2 30·2	93 29 52	A large loose straggling cl of 8th class. The place is that of a double star.	234

No.	Synonym.	Æ 1830·0. h m s	N.P.D. 1830·0. ° ′ ″	Description and Remarks.	Sweep.
383	IV. 20	6 2 48·9	96 11 33	A ✱ 10.11 m has a very sensible nebulous burr, and 3 more are rather nebulous; others in the field are not so.	318
		51·3	12 10	A ✱ 10 m with a v F atmos. Two others s p are free from such atmos. A very F neb suspected s p this object. (N.B. The obs gives Æ 24ˢ·8, but this is a manifest mistake of the wire which corrected = 51·3.)	235
384	VII. 25	6 3 3·8	84 31 38	A p rich, comp cl; one st = 9 m, 3 or 4 = 11 m, and many 12 . . . 15 m. Place that of the D ✱ h 2288.	320
385	Σ. 885	6 7 46·6	83 57 43	The chief of a tolerably neat cl of L stars	320
386	VII. 20	6 12 35·9	97 13 49	Coarse scattered cl; irreg R; st 11 . . . . 15 m	16
		40·0	13 38	Very pretty scatt cl 8 . . . 10′ diam; p rich; stars = 11 . . . 14 m	318
387	Nova.	6 15 0·0	94 36 34	The first ✱ 6 m of a coarse poor cl; st 11 . . . 12 m.	234
388	VII. 26	6 18 32·2	99 33 26	A poor cl of v S stars; rather comp in M stars 12 . . . . 15 m . .	309
389	VIII. 9	6 20 0±	73 12 35	A p rich v loose cl; fills 2 or 3 fields; not b M; st 10 . . 13 m . .	395
390	VII. 5	6 20 34·0	83 3 22	Irreg fig^{d} cl like a hollow triangle in the crowded part of Milky Way; st v S; 12 . . . 15 m; one star 10 m. The surrounding loose stars are all large.	118
391	VIII. 49	6 21 24·5	54 40 24;	Hardly to be called a cluster	51
		38·2:	42 0::	A v coarse straggling cl 10′ diam; 30 or 40 stars 10 . . . 15 m. A ✱ 10 m taken, but one of 7 m precedes to the n.	124
392	VII. 2	6 21 53·1	84 56 28	The place of ✱ 8 m in most comp part of a L, poor, but brilliant cl.	237
393	IV. 3	6 23 17·1	79 43 40	A ✱ 11 m with a milky neb surrounding it, but chiefly on the sp side. The star is not sharp—not stellar, and the neb fades gradually away from the ✱; 70 or 80″ diam; has a ✱ 7 m 30° n f.	120
		20·1:	43 30	A neb with nucl near the n f edge, which has not the sharpness of a ✱, but is dull and dead; = ✱ 13 m; has a ✱ 8 m 6ˢ·55 foll^{s} to n.	121
394	Nova.	6 25 36·3	94 56 40	Place of a ✱ 8·9 m in foll part of a L p rich loose cl; irreg oblong fig; st 12 . . . . 14 m.	235
395	VIII. 3	6 25 40±	81 30 ±	A large tract full of stars; v rich; place from working list. Viewed	118
396	VIII. 50	6 25 52±	84 31 ±	L, p rich; st small; place by working list	237
397	VII. 22	6 26 47·5	82 12 27	A p rich, S cl; irreg fig; st 11 . . . 15 m	118
398	VIII. 48	6 29 31·1	91 19 19	Very coarse; v poor; v straggling; the chief ✱ 8 m taken . .	107
399	IV. 2	6 29 51·1	81 7 18	A ✱ 11.12 m with a p B cometary tail. See fig 64	120
		54·0	6 32	✱ 12 m with B cometic branch 60″ l whose axis is 60° n p. The ✱ is a little ill defined. The apex of the neb comes exactly up to ✱, but does not pass it.	118
		54·3	6 54	Cometic. Has a ✱ 9.10 m 50° n f dist 2′	121
400	VII. 37	6 30 51·0	88 42 20	A great many sc st; and a strong suspicion of a more comp part —(thick haze).	322
401	15 Monoc / VIII. 5 / V. 27	6 31 36·8	79 57 55	A ✱ 5.6 m enveloped in a neb haze. Has about 15 or 16 small stars about it, one of which is a neat D ✱ to s f. (N.B. This is a most remarkable object, being at once a close D ✱, a cluster and a nebulous star.)	120
402	Nova.	6 31 59·9	77 55 32	A poor cl 30 or 40 S st 12.13 m	393
403	VI. 21	6 32 40·2	62 52 2	The most condensed part of a p rich, p comp cl st 11 . . . 15 m; irreg fig; diam of most comp part = 3 . . . 4′; triangular.	115

Fig. 64.

No.	Synonym.	Æ 1830·0.	N.P.D. 1830·0.	Description and Remarks.	Sweep.
		h m s	° ′ ″		
404	VI. 3	6 34 56±	85 16 3	Close cl of v small st; poor; twilight; preceded by a coarse cl of large ones.	237
405	VIII. 36?	6 35 0·9	86 28 13	Coarse sc cl; not v rich; place of * 9 m	320
406	II. 614	6 36 3·2:	56 15 50:	F; S; b M; the southern of two	124
		5·5	16 9	F; forms a D neb with another exactly n	51
407	II. 615	6 36 3·2:	56 13 50:	e F; v S; the northern of two	124
		5·5	14 39	e F; the northern of a d neb	51
408	VIII. 31	6 39 9·3	92 58 10	Loose L irreg sc cl of about 100 st 9…15 m	41
		…	61 +	Viewed; p rich; v coarse; a few st = 9..10 m	235
409	III. 897	6 39 41±	56 19 24:	e F; the northern of two, 3 or 4′ apart	51
410	III. 898	6 39 41±	56 23 24:	e F; the southern of two	51
411	M. 41	6 39 43	110 34 13	Coarse; fills field. The chief, 8 m, is red; a poor cl. (The place is estimated from a D * in the cl.)	236
412	Nova?	6 42 49·8:	96 46 37:	A coarse cl; not v rich; 30 or 40 st; probably only an outlying portion of VIII. 39.	122
413	VI. 27	6 43 1·1	89 20 39	A D * in the chief group of a p rich coarse cl not v comp. Broken into 3 groups. The s p group is the richest. The P D mistaken 5′ in reading off; corrected.	397
		3·9	20 50	The principal D * in a cl; p rich; irreg fig; not m comp	113
		…	20 ±	The brightest * (D h 740) of a fine cl; rich; not v comp; irreg fig.	107
		…	20 45	A fine rich cl 10′ diam; irreg fig; place of a D star	322
414	VIII. 39	6 43 33·5	96 53 30	A v poor S cl; about a dozen st 11 m in a rich region	135
		36·0	53 43	Coarse; p rich; 15 or 20 st in middle, p comp; with stragglers which fill the field.	318
		37·7	52 27	Poor cl; 12 or 15 S stars, and 2 or 3 larger; place of the 2nd star 10 m in cl.	136
415	VI. 2	6 45 2·6:	71 45 28:	A p L comp cl 5 or 6′ diam; irreg fig; p g l b M; place doubtful from temporary instability of the zeros.	333
		18·2	48 53	P rich cl; acutangular, the acute angle precedes; the p side is bounded by a remarkably definite line; pos 223°·4; st 14….16 m. See fig 91.	313
416	VIII. 51	6 46 19·8	96 59 19	Very poor cl; is only an outlier of VIII. 39, the st being more sc, less rich, and larger.	136
		…	……	Viewed. Has no title to be called a cluster.	135
		…	……	Viewed. An outlying portion of VIII. 39	318
417	VI. 18	6 47 46·3	96 59 18	No descrip	318
		48·7	59 25	A cluster, not v rich; 4′ diam; irreg fig; st 12…13 m	135
		49·2	58 59	p rich; irreg R fig; st 13….16 m; strong twilight	136
418	VIII. 60	6 49 22·8	94 22 0	A sc cl of S stars, not rich	41
419	Nova.	6 49 27·1	79 31 10	A poor cluster. The largest star 10 m taken	120
420	Nova.	6 49 27·4	39 10 16	v F; doubtful	329
		32·4	10 50	e F; doubtful. (The agreement of the places dispels the doubt, and shows that a nebula really exists here.)	327

No.	Synonym.	Æ 1830·0.	N.P.D. 1830·0.	Description and Remarks.	Sweep.
		h m s	° ′ ″		
421	II. 304	6 51 27·0	97 33 40	p B; R; S; r; among a multitude of stars	135
		28·7	33 33	p B; R	318
		30·5	32 45	F; S; R; has a * 13 m s, dist 60″	136
422	VII. 14	6 51 42·6	103 28 16	A v coarse loose cl of stars 8 or 9 m	111
423	VIII. 1	6 52 13·1	86 42 39	Place of * 9 m in a v coarse straggling cl of 3 or 4 fields in extent. Only a rich part of the heavens.	239
		14·5	42 23	Linear cl of stars 11 .. 13 m, forming a bent line nearly 15′ long, terminated on the f side by a * 8 m whose place is that here taken.	237
424	II. 861	6 52 37·6	39 10 46	p B; R; p g b M; 15″; n p a * 8 m; pos about 30° s f; dist = 1 diam of neb from edge.	329
425	M. 50	6 54 42·2:	98 5 19::	Rich; comp; fills field; stars 10 . . . 15 m; place of a * 10 m in middle—a fine cluster.	16
		45·5	6 55	A L rather straggling cl 10 . . 12′ diam; st 11 . . . . 15 m. The largest in M, taken.	135
		46·6	6 58	Superb cl; fills whole field; irreg R; stars 11 . . . 15 m; not comp in M; straggling stars extend over a circle 30′ in diameter.	318
		49·4	6 2	A fine v L sc cl; has a red star 8.9 m to s of the more compressed part.	136
426	II. 734	6 55 8·7	39 3 20	e F; R; p s l b M; has a small group of st immediately p like the letter Y.	327
427	VII. 38	6 55 16·0	88 41 39	Fine rich p L cl; st 12 . . . 18 m; 10′ diam. One * 11 m (place taken); straggling.	397
		32·1	38 55	The most comp part of a v L coarse sc cl. The stars 11 . . . 15 m. Towards the north they are 9, 10, and more coarsely sc.	322
		. . .	45 30	Rich L cl; fills field; st 14 . . . 16 m; not comp towards a centre.	113
428	IV. 25?	6 56 8·7	101 4 16	A D * whose L * is in centre of a v F neb which involves the s * also.	130
429	II. 735	6 56 17·3	41 8 6	v F. Among stars	329
430	II. 862	6 56 30·3	39 33 26	F; S; R; p s b M; 12″	330
431	III. 899	6 56 35±	54 37 ±	v F; R; b M; 30″. Æ by working list	124
432	VIII. 40	6 56 54·3	62 33 18	A small cl of 10 or a dozen st 11 . . . 13 m in an ellipse	57
		56·3	32 52	A L coarse straggl cl of L stars. The part taken is a small oval group 90″ diam in the following part.	115
433	II. 736	6 58 8·3	39 33 26	p F; R; g b M; 20″	330
		9·9	34 6	p B; p L; R; g b M; 25″; two s st p	329
434	II. 769	6 58 24·2	70 57 38:	p B; p L; R; g l b M; 40″. In a rich part of the heavens	333
435	Nova.	6 58 38·1:	95 21 59:	Very loose and straggling cluster	122
436	VII. 27	7 1 49·9	98 21 13	A poor straggling cl. Place of a D *	318
437	Nova.	7 5 31·4	101 12 14	A loose straggling cl. Place of a D *	129
438	VII. 16	7 7 14·3	115 26 30	Loose straggling cl; the p part is rather separated from the f, and more comp. Place that of 3 st in the f part.	317
439	VI. 6?	7 7 22·1	75 55 52	A p rich cl of v s stars; irreg; R; 5′ diam; not b M; st 11 . . . 16 m.	393
440	VII. 12	7 10 2·2	105 20 15	A rich cluster of stars 10 m	111

No.	Synonym.	R 1850·0.	N.P.D. 1850·0.	Description and Remarks.	Sweep.
		h m s	° ′ ″		
441	VII. 17	7 11 40·1	114 39 20	A L ✱ 7 m in the centre of a beautiful cl 8′ diam; not v comp; nearly R; not more comp in M; stars 11 ... 14 m.	317
442	Nova.	12 32·5	97 15 8	Two S p close groups of p L st in the Milky Way, rather a remarkable cl.	318
443	Nova.	7 12 55·1	100 4 24	The p star (which is red) of a p rich S cl; fig irreg triangular; ✱s 15 m—in Milky Way.	129
444	II. 316	7 14 49·1	60 11 20	The sp of a curious B double neb or an elongated bicentral neb; nuclei approaching to stars 45° n f to sp 30″ dist.	57
				A double neb close B S R s B M; pos 45° n f or s p—dist of centre 60″. See fig 72.	115
445	II. 317	7 14 50·9	60 11 0:	The n f of the double neb	57
446	Nova.	7 17 20±	55 51 ±	The first of four	128
447	III. 703	7 17 25·5	55 50 ±	A v F neb; another neb s p; the 2nd of 4	128
448	III. 900	7 17 47·5	55 51 40	e F; R; b M; 20″; the 3rd of 4	128
449	III. 901	7 18 0·0	55 48 18	v F; R; p s b M; 30″	128
450	IV. 45	7 19 7·7	68 45 2	A ✱ 8 m exactly in centre of an exactly R B atmosph 25″ diam; the star is quite stellar, not a mere nucl. Another ✱ 8 m distant 100″, and about 85° n p has no such atmos.—A most remarkable object.—Fig 31 (IV. 69) will also represent this neb.	59
451	VIII. 36?	7 20 14±	101 24 ±	A straggling portion of Milky Way	129
452	Nova.	7 21 8·8	17 57 55	A very loose sc cl of large stars, or a starry place	230
453	III. 19	7 21 28·0	79 59 58	e F; R; l b M; = ✱ 15 m; has the f of 4 stars near it	123
		28·5	60 15	e F; among several st 13 .. 14 m; one = 14 m is in the neb ..	120
		...	59 15	Most excessively F	132
454	VII. 65	7 21 34·2	103 37 48	A S cl of v S stars among rich parts of the Milky Way	111
455	VIII. 37	7 25 27·4	105 5 2	A cl with 1 st 9 m; not rich	111
456	II. 821	7 25 44·8	54 24 10	Not v F; S; R; 10″; nearly planetary; but a l hazy; v g v l b M	128
		...	25 ±	A curious, almost planetary neb 10″ diam R; light nearly equable; between 2 S st.	51
457	I. 218	7 26 35·5	50 44 57	p F; L; R; v g b M; 70″; ☾; a L ✱ 8 m precedes 19ˢ·0, and before that is a D ✱.	401
		...	.....	Viewed; not v B; L; p m E in parallel 2′ l, 75″ br; a ✱ 7.8 m precedes 19ˢ·0 and 15″ to s, and preceding this is a coarse double ✱.	335
458	VI. 1	7 28 18·7	68 3 17	A p rich cl; irreg fig; 50 .... 100 st; 11 ..... 18 m; 5 ... 7′ diam.	59
459	VII. 38	7 28 46·4	104 6 28	The chief ✱ of a L, p rich, straggl cl. It is double	111
460	II. 822	7 30 6·5	37 16 50	v F; among s stars; one 8 m precedes at some distance	327
461	Nova.	7 32 59·7	37 31 50	v F; S; R; b M; diam 8″	327
462	Nova.	7 33 26·4	80 20 45	e F; has ✱ 15 m 90″ dist 30° n p	123
463	M. 46	7 34 1·6	104 25 45	The brightest part of a v fine rich cl; stars = 10 m; which fills the field. Within the cl at its n edge is a fine planetary neb.	111
464	IV. 39	7 34 1·6	104 20 25	A planetary neb 3ˢ·75 (time) in diam. Exactly R of a F equable light. Has a v minute ✱ a l n of centre. It is not b M nor fading away, but a little velvety at the edges. At the n edge of the fine cl M 46.	111

No.	Synonym.	Æ 1830·0.	N.P.D. 1830·0.	Description and Remarks.	Sweep.
		h m s	° ′ ″		
465	Nova.	7 35 12·3	34 59 2	Four small stars in a semicircle, within whose concavity there is a F nebulosity, which I am pretty certain is real.	324
466	Nova.	7 37 25·7	114 16 59	A * 8 m followed by a poor cl of 18 ... 20 st, 11' ... 13 m	317
467	Nova.	7 40 31·6	34 5 2	v F; R; v g b M; and losing itself imperceptibly.....	324
468	III. 479	7 42 46·0	80 1 15	A l group of S st which has a neb look, and perhaps there may be neb among them. No other near.	120
		46·0	0 50	A S group of st; with attention counted 5 with power 320°; form a neb group 20″ diam.	123
469	Nova.	7 43 20·4	32 53 12	e F; R; the preceding of two	324
470	III. 836	7 44 14·6	32 52 42	F; R; 15″; the foll of two	324
		15·0	52 22	p F; R; 15″; n p a * 9 m which is 2 diameters of neb dist from its centre.	323
471	III. 830	7 44 51·4	36 41 35	p F; E, or has a v S * s p and a L * n f. Also query if not a v S * in centre.	327
472	IV. 22	7 45 25·5::	115 57 29	A * 9 m with a W of st and nebulosity, or ? if not a v F neb about the stars—(no red colour seen).	317
473	II. 302	7 47 2·2	65 47 28	F; S; R.....	58
474	VII. 10	7 47 27·4::	113 51 51	A cl p rich; v coarsely sc, 10 ... 15′ diam; perhaps 50 st	317
475	III. 837	7 47 59·9	32 59 12	v F; R; g l b M; 15″	323
476	III. 750	7 48 30±	49 43 ±	Viewed by working list; p B even though there is ☾ enough to see the wires well. R; g b and then s b M; 20″.	335
477	Nova.	7 49 3·4	62 31 17	v F; S; R; b M.....	115
478	III. 709	7 49 9·5	38 47 20	F; L; R; v g b M; 60″. Among stars	327
479	VII. 23	7 49 28·1	119 36 24	A fine rich cl; L; stars 12 m and nearly equal; not m comp M about 3′; at the centre equally comp and thence looser.	316
480	VI. 37	7 51 50·1	100 19 34	The 1st * 11 m in the p part of a rich R p comp cl irreg fig; * s 11 ... 20 m, so as to be nebulous. The most comp part = 4′ or 5′ diam.	129
481	II. 554	7 51 57·2	73 49 35	F; R; 15″. Pos of a * 12 m = 225°·5, dist = 60″	395
482	III. 605	7 52 57·7	66 8 31	v F; S; R	59
483	III. 512	7 53 8·6	80 7 15	p B; R; p s b M.....	120
		9·5	7 0	No descrip	132
484	III. 7	7 53 11·0::	80 59 25::	Follows 2 v S st; obs doubtful. Nearly missed obs, owing to the working list being much out in P D.	123
		...	.....	Viewed; F; v S; rather E. 2 st s p. Seen also, but no descrip given, in Sw 132.	120
485	Nova.	7 54 54·0	31 44 52	p F; R; p s b M; s f a * 9 m dist 3′	323
486	III. 877	7 57 35·1	100 57 6	F; L; R; v g b M; 90″; among stars of the Milky Way.....	129
487	III. 752	7 58 10·7	71 41 26	e F; R.....	334
488	VIII. 30	7 58 40±	117 41 22	Cl p rich; v coarsely sc; fills field; st 10 .... 15 m. Æ by working list.	317
489	II. 726	7 59 18·0	55 33 44	p B; R; b M; 40″.....	51
		21·0	32 40	F; L; R; v g l b M; 80″	128
490	III. 840	7 59 27·4	33 50 22	p B; L; R; p s b M; diam 60″ and very gradually fading away; has a * 8 m pos = 164°·3.	324

No.	Synonym.	Æ 1830·0.	N.P.D. 1830·0.	Description and Remarks.	Sweep.
		h m s	° ′ ″		
491	IV. 55	8 1 10·0	43 30 17	p F; R; 60″; very nearly uniformly B, but hazy at edges. It is a resolved globular cluster. Being a remarkably fine night, I see the stars; they are 20 m; a * 9 . 10 m is 40° s f dist 2′.	139
492	III. 710	8 2 14·1	40 25 6	Not v F; L; l E; v g b M; 90″	329
493	II. 719?	8 3 55·4::	53 14 12	v F; R; a coarse d * p points to it. Δ Æ = 1ᵐ 2ˢ	401
494	II. 627	8 4 17·2	68 8 19	F; S; R; has a * 8 m, 4′ dist p	59
495	Nova.	8 5 10·7	31 41 27	p B; S; m E; pos in merid; p s m b M; 15″ l, 6″ br. A * 7 m follows.	323
496	VI. 22	8 5 18·7	95 14 40	Fine L, p rich, very straggling cluster of st 9 . 10 and 10 . 11 m. The straggling edges extend a full field either way. Place that of a D * in the most comp part.	235
		18·8	18 54	A superb cl which fills the whole field; st 9 . 10 . . . . 13 m and none below, but the whole ground of the sky on which it stands is singularly dotted over with infinitely minute points. Place that of a B st, the s of two which point into the concavity of an arc.	234
		26·1:	18 2	A cl of about 100 large st 10 and 11 m	21
497	II. 303	8 8 46·7	66 0 34	p B; R; b M	59
498	III. 256	8 9 11·1	88 43 19	v F; between a * 12 m, s f and one 16 m, n p, the former dist about 1 diam, the latter about ½ diam from the edge.	397
499	III. 606	8 9 21·8	68 57 41	p F; R; p s b M, and then a feeble atmos 25″	334
500	III. 607	8 10 28·2	68 20 44	v F; S; R	59
501	II. 634	8 10 41·2	68 25 6	v F; S; R	59
502	VI. 39	8 12 1·8	119 13 1	A v loose straggling but p rich cl which fills the field, st 9 m and under; v l comp M. Some large st precede it.	316
503	VII. 64	8 12 11±	120 8 +	A fine, p rich cl; stars 11 m pretty uniform 5 . . . 6′ diam. The chief stars make a zigzag line, the outliers extending 20′.	316
504	III. 753	8 15 16·9	69 8 2	v F; R; l b M; has a * 1′ p	63
		20·0	7 43	v F; R; g b M; is 90″ f a * 11 m, and many small st near; windy.	333
		. . .	7 16	v F; p L; v g b M; 40″	334
505	II. 315	8 16 52·7	63 29 23	p B; R; v s b M to a *; 20″	58
506	III. 599	8 17 48·7	67 58 0	v F; irreg fig; has a coarse D * 30° s p, 2′ dist	59
507	III. 234	8 22 12·9	66 52 12	v F; S.	59
508	Nova.	8 22 13·0	36 35 53	e F; S; R; n p a star (about 5° n p). The preceding neb of 2. . . .	328
		22·1	35 10	e F; S; R; 8″; one or other of these Æs is probably affected by an error of 10ˢ in reading off the time.	327
509	III. 292	8 22 50·9::	59 53 1	e F; doubtful obs, as at first the neb was hardly seen. Verified, but too late for a good Æ. In field with a D * which points rather s of it.	56
		57·9	53 31	e F; R; b M; 30″. This Æ preferable	64
510	Nova.	8 22 51·4	36 38 13	F; S; R; about 40° s f a *	328
		55·1	39 30	v F; S; R; 12″. The following and brighter of 2.	327
511	Nova.	8 23 38·4	62 26 52:	e F; a doubt remained; windy	115
512	II. 318	8 24 53·3	60 57 41	F; R; b M.	64
		54·6	57 25	F; irr R; b M	57

No.	Synonym.	Æ 1830·0. h m s	N.P.D. 1830·0. ° ′ ″	Description and Remarks.	Sweep.
513	IV. 35	8 25 34·4	105 34 5	A ✱ 14 m with a fan-shaped brush 15″ l to the s p side; the brush however judged by both Mr. Dunlop (who saw it) and myself not to be in contact. A B ✱ 6 . 7 m, n f.	111
514	II. 319	8 27 8·8	60 43 21 :	v F. Clouded before P D could be well obtained	64
		11·0	43 14	p B; S; R; b M	57
		12·0	43 2	F; L; b M; 60 ... 80″	115
515	III. 257	8 27 15·9 : :	88 42 44 : :	Extremely doubtful, as I could not recover the object	397
516	VII. 63	8 30 15·6	119 21 12	A fine cl shaped like a flattened X. Stars 11 ... 13 m; fills field, but the most comp part = 6′ diam; p rich; not m comp M.	316
517	Præsepe.	8 30 25·1	69 26 23	Præsepe Cancri (M 44) is so very loose and straggling that it would only be noticed as a region rich in L stars;—so also described in Sweeps 59 and 63.	333
518	I. 204	8 31 24·7	39 12 31	p B; p m E; p s m b M; 30″ l; 20″ br	330
		27·1	11 36	B; S; E; p s b M; pos n p to s f	329
		28·0	10 58	p B; p m E; p s m b M, almost to a ✱; 30″ l	328
		30·7	10 50	p B; E; S. A fog coming on	327
519	Nova.	8 32 50·3	93 31 36	A v F cl or r neb; g b M; 80″, one ✱ 17 m distinct; stars and nebulosity; has 2 p B st s and one following.	234
520	I. 288	8 32 59±	11 9 0	v B; l E, in parallel; p s m b M, to a nucl = a ✱ 12 m; 30″. Has a L ✱ p and another f, at a considerable dist.	170
521	III. 49	8 33 9·8	75 6 45	F; R; b M; 12″	395
		12·1	6 24	Not v F; S; R; p s b M; 12″	243
522	II. 727	8 33 17·0 :	54 41 24 :	F; L; R; place badly taken	51
		23·0	41 5	F; L; R; r; 50 ... 60″	128
		24·4	40 22	F; L; R; r	127
523	Nova.	8 35 13·0	35 30 22	e F; p s b M	324
524	Nova.	8 37 50·4	76 46 41	A neat cl of stars 9 and 10 m regularly arranged about a central one. (N.B. This is nearly the place of III. 50, but no neb was noticed.)	241
525	Nova.	8 38 14·8	42 19 9	The chief ✱ of a coarse cluster	139
526	II. 80	8 39 39·4	70 18 42	p B; R; b M. Query if not bicentral	63
		40·8	18 13	v B; R; v s m b M to a ✱; a v F ✱ follows	333
		41·4	17 46	v B; p L; p g m b M; a v S ✱ s f almost involved	334
527	II. 48	8 40 18·4 :	70 21 46	The faintest object imaginable, and discerned with the utmost difficulty. Sky perfectly clear.	334
528	VIII. 10	8 40 37·9	77 67 21	A poor cluster of 4 or 5 large and a few sc s st	242
		62·1	61 30	The chief star 9 . 10 m of a place rich in stars	120
		63·2	59 51	A v coarse and poor cl. Place of a D ✱	241
		...	60 5	An insignificant cluster. No other near	123
529	III. 294	8 41 8·8	58 30 3	p B; R; v g m b M; 15″	56
530	I. 242	8 41 15·1	38 3 13	B; L; v s m b M to a ✱ 10 . 11 m, but sharply defined. It is a neb ✱ with a v F extensive nebulosity.	328
		16·3	2 45	v B; v s m b M to nucl. Seen through thick fog; a L ✱ s f dist 10′ and 2 S st p near.	327

No.	Synonym.	R 1830·0.	N.P.D. 1830·0.	Description and Remarks.	Sweep.
		h m s	° ′ ″		
531	M. 67	8 41 29·4	77 32 3	Pretty rich cl of sc st 10....15 m	17
		49·6	33 47	200 st, more or less; it fills field; st 11...15 m. It is preceded by a rich region of st 9...10 m.	19
		68·4	34 56	Superb cl very rich and brilliant; fills field; stars 9....15 m; straggling at edges and not very comp in M.	241
		75·9	35 2	100 or 200 st coarsely sc 11...15 m	22
		...	34 13	A cluster. No further descrip	242
532	I. 200	8 42 5·0	55 57 42	v B; v L; m E; 45° n f to s p; g m b M; 5′ l; 40″ br; windy	127
		5·5	57 25	v B; v L; g m b M; 5′ l; 50″ br; E 45° (s p by diag)	128
		6·3	56 0	v B; v m E; pos 40°·9 by microm 4′ l; 1″ br; p g b M; 4 stars near	337
533	III. 712	8 42 53·4	40 12 1	v F; p L; R; 30″; a * 12 m s f (one semidiam from edge) and one 13 m, n p.	330
		56·1	11 56	p F; R; g b M; 20″	329
534	III. 831	8 44 37·6	37 17 13::	v F; S; R; p s b M	328
535	II. 823	8 44 43·6	38 0 18	p B; m E nearly in merid; p s b M	328
536	II. 880	8 45 49·6	92 25 19	p B; S; E nearly in parallel between 2 st of 12 and 15 m, each half the length of the neb from the adjacent extremity. See fig 61.	21
537	IV. 66	8 46 33·4	35 35 7	A * 11 . 12 m with a p B fan-shaped neb appendage in which there seems to be one v F *. A curious object. See fig 65.	324
538	Nova.	8 47 2·6	92 32 49	v F; R; r; 30″; stars suspected in it. A * 9 m precedes. This may possibly be II. 281 with an error of 10′ in P D, but I have no reason for believing my obs erroneous.	20
539	Nova.	8 47 17±	10 8 ±	p B; S; E from n f to s p. Has a * n f.....	171
540	Nova.	8 48 1·8	44 26 37	p B; L; E; v g b M; 2′ l; 1½′ br; with attention a central point is seen = a * 18 m.	139
541	III. 540	8 49 32·1	53 37 12	A strong suspicion of a neb, but clouds prevented verification..	331
542	II. 557	8 49 48±	83 0 ±	F; p L; R. R from working list, and P D hardly more than conjectural.	116
543	II. 529	8 50 28·9	94 14 10	v F; R; v g b M; p L; 60″	235
		29·7	15 6	p F; R; v g b M; 25″	234
544	Nova.	8 51 13·3:	53 35 47	e F; S; R	401
545	II. 834	8 51 28·3	29 23 47	e F; R; quite certain.....	404
546	Nova.	8 52 31·3	92 43 19	v F; L; R; b M.....	21
547	Nova.	8 53 0±	93 3 54	e F; R. R between 52ᵐ 31ˢ and 54ᵐ 41ˢ.....	21
548	Nova.	8 53 34±	12 49 ±	p B; p L; E; v g l b M; 90″ l; 40″ br.....	171
549	Nova?	8 53 56·4	37 34 23	Four small st with a strong suspicion of nebula among them ..	328
550	I. 249	8 54 2·7	28 51 20	v F; p L; R; v g b M; 60″; ((. A * 8 m n p.....	404
551	III. 60	8 55 1·4	70 53 2	v F; R; has a double * to n.....	63
		1·8	51 56	v F; is s of a coarse double *	334
552	III. 825	8 55 21·2	53 56 35	Near a *, but doubtful	337
		21·8	56 27	e F; has * 12 m 45...50° n p; dist 60″.....	401
		22·5	56 45	e F; R; v g l b M. A * 11 m 75° n p; 40″	128
		23·4	57 27	e F; S; s of a st 12 . 13 m	127

Fig. 61.

Fig. 65.

No.	Synonym.	R 1830·0.	N.P.D. 1830·0.	Description and Remarks.	Sweep.
		h m s	° ′ ″		
553	II. 828	8 56 40·4	35 28 17	p B; p L; l E; v g l b M	324
554	III. 647	8 57 38·4	51 41 37	p F; R; S; but not nearly so F as II. 825, which precedes it in the sweep.	401
555	I. 250	8 58 19·3	29 16 31	p B; l E; p s b M; 50″ l, 45″ br	404
556	Nova.	8 58 22·8	38 55 31	e F; s b M to a ✱ 15 m; the first of 3	330
557	III. 236	8 58 32·7	67 52 22	No description	59
558	II. 520	8 58 42·8	85 55 30	v F; p L; g b M, but not to a nucleus	238
559	Nova.	8 58 43·7	38 54 1	Not e F; l E; b M. The second of 3	330
		45·5	53 16	Not v F; l E; S; p s l b M; 15″	329
560	II. 275	8 58 49·0	104 49 14	e F; p L; has a small ✱ just n, and four more preceding	111
561	Nova.	8 58 52·2	38 57 21	v F; R or v l E. The last of 3 S neb	330
		54·1	57 6	v F; S; l E; 10″	329
562	II. 490	8 59 3·5	56 11 20	F; m E in direction 45° n p; 3′ l, 1′ br	128
		6·5	11 24	F; E 75° n p ... s f; 90″ l, 30″ br	51
		7·6	11 7	F; L; m E; pos n p ... s f	127
563	Nova.	9 0 55·5	44 21 2	p B; v L; R; v g b M; r; 3′ diam. ℭ	139
564	I. 2	9 1 14·8	82 16 27	p B; R; g m b M	18
		17·9	16 26	v B; R; p s b M; 2′ diam; the hazy border perhaps extends further; r::	116
565	III. 61	9 1 20·1	71 37 42	v F; S; r. My MS obs makes the P D 70°, but my father's obs makes it 71°. Each relies on a single obs. Of course I prefer 71.	63
566	II. 546	9 1 50·5	54 17 34	p B; S; R; m b M; 20″	51
		51·1	16 40	B; R; v s m b M; 20″	337
		52·7	16 27	p F; R; b M; 30″	127
		54·0	16 35	Not v F; R; p s b M; 25″	401
567	III. 825	9 2 11·9	54 22 31	v F; S; 7ᵐ·5 following a S double ✱	337
568	I. 167	9 3 4±	49 16 ±	Viewed. Found in place as determined by my father. No description.	335
569	I. 66	9 3 25·1	104 7 31	p B; E in parallel; p s b M; 60″ l	111
570	I. 216	9 3 39·8	20 4 51	F; E in parallel; p s b M; 30″	377
571	I. 59	9 4 44·4	113 30 4	p B; R; g b M; 25″	317
572	Nova.	9 6 19·4	54 52 10	v F; R; has a D ✱ 5′ n; 1ᵃp	128
		21·5	51 15	v F; S; R	337
573	III. 296	9 6 28·3	58 24 28	The faintest conceivable.	56
574	III. 832	9 6 31·7	36 46 48	A ✱ with v F neb attached, in which is involved another ✱ 10″ dist.	328
575	III. 62 } III. 63 }	9 6 38±	70 20 33	A S F close double nebula. The individuals are 30″ asunder. Place hardly more than conjectural in P D. R by working list.	63
576	II. 868	9 7 12·0	25 2 45	v F; S; near a ✱ 8 m	410
577	Nova.	9 7 12·4	69 5 56	v F; S; R; the n p of two, distant 8′	59
578	Nova.	9 7 30·0::	69 14 19:	v F; S; R; the s f of two, distant 8′	59

No.	Synonym.	$\mathcal{R}$ 1830·0.	N.P.D. 1830·0.	Description and Remarks.	Sweep.
		h m s	° ′ ″		
579	Nova.	9 7 56·5	28 50 33	F; p m E	410
580	II. 505	9 8 12·2	105 35 52	p B; E to n f; p s b M; 60″	111
581	Nova.	9 9 0·5	55 33 25	e F; E	337
		...	33 0	v F; it is the s p of two. The other is I. 113	51
582	I. 113	9 9 22·0	55 32 24	B; R; b M	51
		23·0	55 31 50	p B	337
583	III. 627	9 9 55·9	49 59 46	p F; S; R	335
584	I. 205	9 10 14·0	38 18 3	v B; v m E; v s m b M; pos 150·8; comes up to a nucleus, a star 10.11 m; has 2 st not involved 11 & 12 m, and a 3rd 10 m perp to axis of neb.	328
585	Nova.	9 10 20·8	105 45 43	e F; R; b M; precedes a * 8″·5	111
586	III. 827	9 10 22·1	53 54 57	v F; not v S; R; 100″....120″ s f a * 10 m	127
		...	.....	Viewed. It is 1 field ($1^m\frac{1}{2}$ ±) f a v B * 6.7 m	128
587	III. 488	9 12 5·8	105 47 43:	v F; L; E n f to s p; 1 b M. It is 9″·5 in $\mathcal{R}$ preceding a * 11 m, and is S of the *.	111
588	III. 629	9 12 25·9:	49 8 56:	v F; S; R; has a * 10 m 2′ dist prec. The first of 2	335
589	III. 714	9 12 26·6	40 4 56	v F; p L; R; v g b M. The preceding of 2, making an isosceles triangle with the other and a star.	330
		28·8	4 36	p F; R; p s l b M; 20″. The s p of 2, making an isosc triang with a * 9 m.	329
590	III. 630	9 12 29·4:	49 7 6::	e F; p L; v g b M; the following of 2	335
591	III. 713	9 12 40·4	40 2 1	p F; l E; v g b M; the foll of 2	330
		41·7	1 31	Not v F; R; p s b M; 20″; the n f of 2, making isosc triang with a * 9 m.	329
592	I. 132	9 13 14·6	101 11 24	p B; R; 45″; p g m b M; almost to nucl	129
593	I. 137	9 13 53·5	54 45 4	B; R; m b M; 40″; not resolved with 240	51
		54·9	45 40	B; R; p s m b M; almost to a nucleus	128
		55·5	46 11	v B; R; v s m b M, to a *; follows a * 7 m and is 3′ S of it.	336
594	III. 520	9 15 20·6	99 42 26	F; extended between 2 stars 12 & 16 m	129
595	III. 846	9 15 24·3	31 54 7	v F; p L; l E; v g l b M; 35″ l, 30″ br	323
596	I. 260	9 16 10·8	26 46 41	p B; R; p s b M; 20″. Among stars	411
		10·9	46 52	p F; R; S; v g b M; 40″; a * 12 m follows. $\Delta\mathcal{R} = 16^s·5$; pos = 72°·6.	404
597	II. 546	9 16 26·0::	77 49 48:	The bisection at 16^m 31ˢ·1, 50′ 33″; dist of centres 2½′ or 3′	17
		28·6	50 10	The preceding, brightest, and most condensed of two; both B; R; p s b M.	120
		29·0	50 12	The p of a double neb, both R; g b M; 40″; dist from each other 90″ ±. The bisection observed at $\mathcal{R}$ 16^m 32ˢ·0; P D 77° 50′ 21″.	19
		30·7	49 49	p F; S; R; p s b M; the n p of two. Pos of the other from this = 110°·6.	242
		32·1	50 56	v F; S; R; the n p of two. Pos of the foll 107°·3	241
		32·2	50 32	The first and brighter of two	123

No.	Synonym.	R 1830·0.	N.P.D. 1830·0.	Description and Remarks.	Sweep.
		h m s	° ′ ″		
598	II. 547	9 16 33·6	77 51 0	The f and fainter of 2 p B; p s b M	120
		35·0	50 32	The f of a D neb. R; g b M; 40″	19
		35·7	50 39	F; R; g b M; the s f and larger of 2, pos from the 1st = 110°·6	242
		35·7	50 47	The fainter of two 25° s f	123
		36·1	51 11	v F; S; R; the s f of 2	241
		36·2::	51 18::	The f of a double nebula. See II. 546.	17
599	Nova.	9 17 59±	66 15 17	e F; v S; E in parallel; R very uncertain	59
600	III. 555	9 18 57·6	100 54 29	p B; p L; R; v g l b M; 80″. The MS makes the P D 101°, but two agreeing obs of my father prove this to be a mistake.	129
601	Nova.	9 19 59·4	31 46 37	v F; R v g b M; 15″; has a coarse D * 7′ s	323
602	III. 297	9 20 12·8	59 41 1	F; v s m b M to a * 12 m	56
		13·2	43 22	S; R; s b M; 20″; has a * 8 m 55° n f dist 3′. N.B. The working list very erroneous in P D. An extraordinary difference in these obs.	115
603	III. 8	9 20 26·4	81 31 56	2 or 3 st and nebulosity	116
604	I. 56 I. 57	9 22 32·2	67 45 5	v B; v L; E; 3′ long. An approach to a 2nd nucleus. See fig 70	59
		32·3	45 45	An e F, R, neb. Appended n f to a v L, R, v B, one p s b M, but not to a *.	246
		...	47 ±	I. 56 is v B; E; g b M; r. Long attention shows a v F, L, R, neb attached n f.	244
605	Nova.	9 22 57·5	23 18 23	e F; S; p s b M; 12″	412
606	II. 495	9 23 1·2	80 48 56	p F; S; l E	134
		1·9	49 46	F; not v S; R; g l b M	116
607	II. 506	9 23 38·0	105 59 36	F; b M; l E s f; 30″	111
608	II. 40	9 24 38·5	79 6 0	F; R; b M; 40″; the preceding of two	123
609	III. 513	9 24 56·3	79 8 30	v F; R; b M to a nucleus; 25″	123
610	II. 260	9 25 10·4	67 32 38	No description	246
		19·7	32 38	F; S; R. Seen also in Sw. 244 in its place by working list, but no place taken.	59
611	III. 298	9 25 36·4	57 33 2	F; R; v s b M almost to a *	56
612	III. 963	9 27 11·2	12 39 46	e F; has a coarse D * 3′ following	414
613	Nova.	9 28 53·7	55 14 5	v F; v L; l E parallel to merid; v g b M; has a * 10 m following	128
		53·8	13 40	Not v F; L; R; v g l b M; 40″	337
614	III. 4	9 29 1·7	79 42 56	Not v F; S; l E; p s b M	134
		3·9	44 25	e F; R	123
		...	43 ±	v F; R; v g b M; 30″	120
615	III. 519	9 30 3±	82 16 ±	e F; p L; v g b M. R by working list	116
616	IV. 68	9 30 4·5	30 23 37	S; R; v s v m b M, yet not to a nucleus	323
		6·3	22 48	p B; R; s m b M; almost to a *. Has a * 11 m 20″·0 p and 15 or 20″ n. R very precarious.	404
617	Nova.	9 30 15·4	16 14 7	e F; has a * 13 m near	382
618	Nova.	9 30 38·0	20 37 19	F; R; p L; v g l b M; 40″; is s of a S group of st	377
619	III. 315	9 30 47·4	16 15 37	v F; R; b M	382

No.	Synonym.	R 1830·0.	N.P.D. 1830·0.	Description and Remarks.	Sweep.
		h m s	° ′ ″		
620	III. 541	9 30 56·1	53 20 57	F; pL; R; vglbM; 30″; has * 18 m 30″ p	331
621	Nova.	9 31 50·8	85 37 57	vF; R; gbM	18
622	I. 114	9 32 45·7	57 25 ±	B; vL; E; vgbM; 2′ l, 1½′ br. PD estim	128
		47·5	22 32	B; vL; vglbM; E; 2½′ by 1½′	127
		47·8	22 30	vB; vL; 1st class rather E; 2′	337
		47·8	23 23	B; E; gbM; 60″. The sp of two	56
623	III. 751	9 32 57·1	52 58 27	vF; R; bM; filamentous (i. e. as if filaments hung round it; an effect probably of diverging lines of small stars, as in M 13. See fig of this last. This appearance therefore indicates its consisting of stars).	331
624	II. 491	9 33 0·2	57 17 0	pB; pL; E	128
		4·3	18 23	pB; R; gbM; 30″	56
		6·3	17 13	B; pL; 60″	337
		6·5	17 17	pB; R; vgbM; the n f of two	127
625	I. 285	9 33 4·2	21 18 13	B; vL; m E in pos = 332°·4; vgvlbM, 3′ l, 1′ br; has several S st in it, and one 12 m nearly at right angles to the axis of extension	411
626	II. 275	9 33 16·8	88 53 45	pB; L; R; vglbM; 75″; r; well observed (and correctly reduced).	113
		22·4::	53 54	F; L; R; vglbM; 50″. R approximate	397
627	Nova.	9 33 20·2	57 12 54	F; the foll and most northern of 3	128
628	III. 527	9 33 30·3	97 49 20	eF; R; vlbM	136
629	I. 78	9 33 53·9	16 56 19	vB; R; pgmbM; 50″; has a * 13 m following 1′ dist, exactly in the parallel.	382
630	I. 61	9 33 56·8	92 56 9	B; R; bM. A * 9 m precedes 3ᵐ·0, and is s of neb	21
631	III. 521	9 34 49·1	99 36 49	pB; R; psbM	129
632	III. 528	9 34 50·0	98 49 54	eF; pL; vglbM	136
		54·7::	50 29:	F; R; bM; a hurried and imperfect obs	129
633	III. 34	9 35 49 ±	78 14 ±	eF. R from working list; PD rough approx	123
		...	11 ±	vF; R; bM. PD only a rude approx	338
634	Nova.	9 37 14·2	67 11 53	F; vS; bM. The sp of two	59
635	III. 277	9 37 31·6	103 32 56	Not vF; R; bM; 30″	111
636	Nova.	9 37 36·4::	67 8 19	F; vS; R; bM. The n f of 2; pos 40° n f	59
637	III. 278	9 37 38·1	103 35 11	pF; R; bM; 25″	111
638	II. 717	9 38 7·3:	45 7 12:	pB; irreg R; bM; r	139
639	V. 26	9 38 27·5	55 47 59	A singular curved wisp of nebula. It curls up and tapers off at the s p side, and is clubbed at the n f extremity.	51
640	Nova.	9 39 6·4	44 53 34	Not vF; R; bM; r. The first of 2	138
641	Nova.	9 39 12·4	44 52 0	F; psbM; r; stars seen. The second of 2	138
642	Nova.	9 39 54·6	76 23 44	F; pL; R; glbM; 50″	240
643	V. 23	9 40 25·9	17 0 3	eF; vL; vglbM; 3′ l; 2½′ br	382
644	Nova.	9 40 32·9	94 25 21:	eF; L; 60″. The preceding of two	234

No.	Synonym.	R 1830·0. h m s	N.P.D. 1830·0. ° ′ ″	Description and Remarks.	Sweep.
645	I. 115	9 40 50·5	55 39 34	pB; R; bM; has a * 10 m 20° s f, dist 30″	51
		53·9	39 0	vF; R; bM; has a * 10 m s f	128
646	III. 51	9 40 52·3	76 23 9	eF; pL; R	338
		53·0	23 54	eF	243
		55·1	23 59	vF; E nearly in parallel; v g b M; 30″ l, 20″ br	242
647	Nova.	9 41 8·5	94 22 51	F; R; v g l b M; r. The following of 2	234
648	III. 52	9 41 16·6	76 28 0 : :	vF; pL; E. P D estimated from III. 51, which precedes	242
649	M. 82	9 41 16·9	20 7 49	eB; eL; E, pos = 156°·0; g b and then s v m b M, with faint rays of light nearly to extremities of field (15′). The most condensed part is 4′ l and 3′ br.	377
650	Nova.	9 42 13·4	59 58 41	pB; S; p s b M; between 2 B st	408
		17·4	58 52	A * 12 m with an e F neb atmos about 10 . . . 12″. It is between a * 8.9 m n p and one = 10 m, s f, neither of which are so affected. A curious object.	115
651	II. 835	9 44 4·2	29 53 45	pF; S; R	406
		14·9	54 47	eF; pL; 35″; v g b M; has a * 10 m 7′ n	323
652	III. 254	9 44 53·6	87 37 44	vF; mE, pos = 111°·5; 80″ l, 15″ br. Aurora in sky, even at this P D.	397
653	II. 903	9 45 41·3	13 1 41	Very doubtful. ☾ and haze	414
654	II. 333	9 46 1·4	17 0 57	vF; S; R; 10″; near * 11 . 12 m	382
655	II. 334	9 46 16·4	17 3 48	F; R; 20″; v g l b M	382
656	VI. 4	9 46 23·4	84 55 38	pB; g b M; r; 1E; 60″ l, 40″ br; twilight. No other cluster or neb near.	143
		26·8	56 9	eF; R; v g b M; a very condensed cl or r nebula. A * 8 m follows.	238
		. . .	. . . . .	eF; difficult to see for ☾. It is like a v F r neb 2 or 3′ diam; precedes * 6 . 7 m about $1\frac{1}{2}^m$.	237
657	II. 492	9 48 21·1	56 49 35	F; 1E; 30″; has * 9 m 6′ f	337
		22·0	49 4	pB; E; has a * 9 . 10 m n f	51
		22·5	49 25	pB; pL; E in parallel; g b M; 60″ l, 40″ br; has * 10 m n f	128
658	I. 286	9 48 33±	20 26 45	B; R; p s b M; 60″. R from working list, but found in its place.	377
659	I. 272	9 49 2·8	78 50 13	pB; pL; R; g b M; 40″	123
660	III. 542	9 49 31·1	53 47 17	eF; R; v g v l b M; 60″; has a * 10 m in parallel, dist 7′	331
661	III. 24	9 51 36·7	66 47 19	vF; S	59
662	III. 916	9 52 27·8	29 4 51	F; vS; R; b M; a coarse D * n f points to it; has a * 11 m 30″ dist, pos 142°·2.	406
663	Nova.	9 52 38·7	64 28 23	pB; S; mE in parallel; 30″ l, 10″ br; b M to nucleus	58
		42·2	28 58	pB; mE; p s b M; 30″ l; 10″ br	407
664	III. 478	9 52 39·6	56 28 35	eF; S	337
		40±	27 24 : :	eF; doubtful	51
665	IV. 48	9 53 29·1 : :	48 26 51 : :	A v S * 14 m seems to have some nebulous appendage, but ☾ troublesome.	335
666	II. 320	9 54 13·3	57 59 42	F; S; R; s m b M; is equal to a * 12 m	56

No.	Synonym.	R 1830·0. h m s	N.P.D. 1830·0. ° ′ ″	Description and Remarks.	Sweep.
667	Nova.	9 55 19·5	41 54 49	pB; R; smbM; 20″	138
		19·8	55 2	Not eF; S; R	330
		21·6	54 36	B; R; psmbM; almost to a * 12 m	329
668	I. 163	9 56 45·3	96 53 33	vB; L; mE; vsmbM; almost to a nucl; 3′ l, 30″ br. With 12 inches aperture, its nucleus is rather speckled; with 6 inches it is barely discernible as a neb. P D by MS 97°, but my father's obs makes it 96°. Each has but one obs. Of course I prefer 96.	136
669	III. 65	9 59 2±	70 45 ±	eF; S; R. Forms a triangle with 2 st. R by working list; P D rough approx.	332
670	Nova.	9 59 9·3	79 12 0	eF; S; psbM; follows 31 Leonis 16ˢ·5, and is 1′ 40″ s of it	123
671	Nova.	9 59 16·0	70 56 6	pB; pmE; gbM; 40″ l, 20″ br. Found in looking for III. 65 by working list.	334
672	Nova.	10 0 17·0	43 12 27	F; R; gbM; 25″	139
673	III. 518	10 1 49·6	101 35 29	F; L; R; vgbM; 60″. In field with λ Hydræ	129
674	I. 79	10 2 8·9	15 45 46	vB; L; R; at first vg, then vs, vmbM	382
675	Nova.	10 2 52·5	38 40 33	A star 7 m has a photosphere 2 or 3′ diam. Sky perfectly clear; glass quite clean; windy. Another * of same magnitude viewed presently after has no photosphere.	328
676	Nova.	10 3 ±	14 45 ±	vF; S; R. R extremely precarious	171
677	III. 53	10 3 31·7	76 29 59	eF; pL; R	242
678	II. 639	10 3 43·5::	50 24 39::	B; R; psbM; 35″	335
679	Nova.	10 3 47·6	32 29 57	eF; R; vglbM; 15″	323
680	III. 255	10 3 51·9	86 1 38	pB; S; R; psbM; 15″	143
681	II. 640	10 4 0·5::	50 31 21::	F; R; gbM; 30″	335
682	II. 43	10 4 2·3	66 25 20	pB; L; R; glbM; a * 10 m precedes	244
		3·9	25 43	Not vF; L; R; vglbM; 70″	246
		...	26 ±	pB; pL; bM; r	59
683	Nova.	10 4 39·5	28 55 45	F; psbM; like a star rubbed out. A * 7.8 m in field n p—dist 5′.	406
684	I. 3	10 4 54·9	85 44 18	B; pS; R; psbM; 25″	143
		56·4	43 54	pB; R; psbM; 20...30″	238
		57·1	44 33	B; R; psmbM; the preceding and brighter of two. Δ R = 29ˢ·25	237
		64·8::	43 27	B; R; gbM; 60″. The p of 2. (The R very precarious, the chronometer not being then in use.)	18
685	I. 4	10 5 24·2	85 41 30	B; R; psbM; 30″. Has a * 10 m 20° n f, dist 90″	143
		24·7	42 9	B; R; pgmbM; the foll and fainter of 2. Δ R = 29ˢ·25	237
		26·2	41 49	pB; lE; 30″; has * 12 m n f; pos 78°·2; 70″ dist	238
		33·8::	40 27	B; R; gmbM; 60″; the foll of 2. R very precarious	18
686	Nova.	10 5 39·6	42 33 47	F; S; R	139
687	III. 25	10 7 11·2	68 1 31	Not vF; S; R; psbM; 16″	246
		12·0	1 40	Not vF; S; R; psbM	244
		12·7	2 16	pB; pL; R	59

No.	Synonym.	R 1830·0.	N.P.D. 1830·0.	Description and Remarks.	Sweep.
		h m s	° ′ ″		
688	I. 168	10 8 1·2	47 44 7	F; vL; R; v g b M; a ✱ 8 m p, 10′ dist	248
689	Nova.	10 8 4·5::	47 32 11::	p F; v L; R; v g b M; 12ˢ·5 of time in diam; has a ✱ 11 m 2′ north.	335
690	III. 910	10 8 15·6	31 44 12	e F; p L; 30″	323
691	Nova?	10 8 34·0	42 42 52	F; S; R; b M; 15 ... 20″. If this be III. 704, there must exist a great error in P D on one or other side.	139
692	II. 44	10 8 42·6	67 19 5	B; p m E; p s b M	244
		43·3	19 13	p B; E; g b M; 45″ l, 40″ br	246
		44·8	19 26	B; E; s b M to nucl; 60″ l; the s p of 2	59
693	II. 45	10 9 1·5	67 15 35	B; R; has a ✱ 8 m n, dist 60″. The n f of 2	59
		2·0	15 20	p B; R; p s b M; pos of a ✱ 10 m from neb = 352°·0	244
		2·2	15 33	B; R; p s b M; 30″; has ✱ 10 m n p, 90″ dist	246
694	III. 348	10 9 11·7::	61 29 31::	So e F that I remained unsatisfied	57
695	I. 199	10 9 23·3	43 35 19	F; v L; b M; m E; 6′ l, 2½′ br; r	140
696	II. 720	10 10 16±	46 9 45::	v F; R; v g b M; 30″; the preceding of 3 neb in a triangle. Some stars near.	248
697	I. 266	10 10 30·6	32 13 7	v F; L; E; v g l b M; 2′ l; 1½′ br	323
698	Nova.	10 10 31·0	61 19 57	F; L; 40 .... 60″; g b M	115
699	II. 721	10 10 32·5	46 11 52	v F; R; v g b M; 30″; the second of 3 in a triangle	248
700	II. 722	10 10 44·1	46 9 52	v F; R; v g b M; 30″; the last of 3 in a triangle	248
701	Nova.	10 11 6·0	63 38 48	F; R; 30″; has a ✱	58
702	III. 330	10 12 14·7	65 12 54	e F; R; 20″	407
703	II. 882	10 13 42·2	31 0 17	p F; L; E; v g b M; 30 .... 40″	323
704	Nova.	10 14 11·9	22 20 3	A cluster of 20 stars more or less, 10, 11 and 12 m, scattered over a space 10′ diam. A star 7 m s.	412
705	Nova.	10 14 38·9	76 35 4	A very close D ✱ of the first class involved in a nebulous wisp. "A most curious, delicate and interesting object." This is my double star No 2529.	243
		39·2	34 54	A triple star in a nebula, a fourth ✱ suspected	242
		40·5	36 ±	A double ✱ in v F nebula	388
706	Nova.	10 14 57·3	62 7 2	p B; R; p s b M; 30″	115
707	Nova.	10 15 12·3	27 52 13	e F; S; p s b M; 8″; 2 st 11 and 12 m follow	406
708	III. 883	10 15 29·1	31 55 22	Not v F; R; p s l b M; 20″	323
709	III. 631	10 15 41·0::	49 30 46::	p F; R; S; p g b M; 10 ... 12″	335
710	IV. 10	10 15 53·1	71 59 2	A ✱ 9 m, with v F neb. atmosph, rather excentric. Has 2 st p and ? another v S ✱ f.	332
		53·2	59 42	A ✱ 9 m, with a v F neb. The ✱ is excentric, and has another ✱ foll at extreme edges.	63
711	I, 86	10 17 42·6	60 37 5	v B; R; g m b M; 40″	68
		43·1	37 51	v B; R; p s m b M; r; 40″	408
		43·5	37 52	v B; m E; v s m b M; 40″ l, 15″ br	343
		43·9	38 22	B; E; comes up to a nucleus	57
		...	38 31:	v B; E; comes to nucleus. Transit missed	66

No.	Synonym.	R 1830·0. h m s	N.P.D. 1830·0. ° ′ ″	Description and Remarks.	Sweep.
712	Nova.	10 17 52·5	85 16 38	e F; S; R; two st, 10 and 11 s p, dist 90″	142
		...	18 ±	e F; has a * 6 m, 30° n p, dist 8′	143
		...	.....	Viewed. It is 31ˢ·5 foll a * 6.7 m, and makes a triangle with 2 S st.	238
713	II. 374	10 18 22·2	66 17 25	p B; R; S; p s b M; 15″	244
		23·0	17 17	No description	246
		...	17 25	F; S; b M	59
714	I. 72	10 19 43·5	59 38 19	p B; E; b M	68
		47·3	38 37	p B; R; s b M	6
		...	38 ±	F; R; p s b M; 40″; has coarse D * 23ˢ·0 f	341
715	II. 870	10 20 34·7	24 5 41	F; R; g b M; 18″	411
716	Nova.	10 21 21·4	33 2 27	e F; between 2 S stars	323
717	II. 871	10 21 22·1	24 23 6	v F; R; p s m b M; almost to a star	411
718	III. 349	10 21 32·3	60 20 18	p F; a * very near or else extended	408
		34·2	20 17	p B; R; p s b M	343
		35·4	20 32	p F; S; b M; has a * s f	115
		36·4	20 32	v F; S; R	57
719	III. 331	10 22 4·2	64 15 18	F; E; g b M	58
720	II. 358	10 22 45·0	61 27 23	F; R; 25″	415
		45·3	27 56	v F; R; g l b M; 30″	408
		47·1	27 31	F; has a D star f	66
		50·3	28 22	p B; p L; R; b M	115
721	II. 359	10 23 22·3	60 36 32	B; R; g b M; 30″	68
		23·3	37 28	p B; v S; R	57
		23·4	37 26	B; R; p g m b M; 15″	408
722	III. 917	10 25 10·9	30 30 57	v F; p S; R; p s l b M; 15″	323
723	III. 918	10 25 14·4	30 34 17	e F; S; R; v g l b M; 12″	323
724	I. 164	10 26 28·6	51 48 2	p B; m E; g l b M; 2′ l, 45″ br	331
725	III. 767 ?	10 26 53·7	39 0 36	v F; two distant stars nearly on parallel	329
726	III. 54	10 27 22·0	76 25 23	p L; so faint as to be barely perceptible, but a sure observation.	338
727	III. 55	10 27 34·1	74 57 2	F; R; g b M	24
		35·0	57 34	e F; S; R; p s b M; 10″	243
728	II. 46	10 27 38·7	67 14 19	B; R; p s m b M; 35″	244
		40·6	14 38	B; E; nearly lost by looking too late	59
		...	16 ±	No descrip. P D only rudely taken to satisfy myself of an error in my father's place, as shown in the working list.	246
729	III. 615	10 27 48·4	51 40 2	e F	401
		51·3	40 17	v F; S; p s b M; 12″	331
730	III. 66	10 27 49·5	70 59 57	v F; v S; R; l b M	63
		50·0	59 6	v F; S; R; g b M; 12″	334
Fig. 40. 731	IV. 60	10 28 6·6	35 36 32	B; R; v s m b M, so as to form almost a disc 15″ diam. Surrounded by a v feeble atmosphere. See fig 40.	324

No.	Synonym.	Æ 1830·0. h m s	N.P.D. 1830·0. ° ′ ″	Description and Remarks.	Sweep.
732	II. 745	10 29 22·4	41 43 6	F; m E; between a * 10 m and 1 of 14 m	329
		25·6	41 17	v F; E in a direction between 2 small stars 13 m and 11 m, from s p to n f. (Fog.)	330
733	Nova.	10 29 52·2	12 17 24	p B; S; p s m b M	413
		57 ±	16 ±	p B; irreg R; p s m b M; 15″	171
		61·2	18 11	p B; l E; g b M; 25″. The obs makes the P D 13°, but there can be no doubt that this neb is the same as that of the two preceding observations.	414
734	II. 348	10 30 37·7	65 1 48	v F; R; g b M; 30″	407
		39·2	1 38	v F; S; has either a * which gives it an apparent elongation in parallel, or is a double nebula.	58
735	II. 641	10 31 45·0	51 48 56	v F; R; b M	401
		...	47 ±	F; R; 30″. Taken much out of merid. P D only approximate.	331
736	III. 317	10 32 55·9	15 45 28	not v F; R; g b M	382
737	II. 77	10 33 6·3	75 22 7	F; E; p L; 60....90″	24
		7·3	22 39	F; E; p L; v g b M; follows a * 7 m 10ˢ·0	242
738	I. 80	10 34 9·6	16 15 59	B; R; p s b M; 40″; has * 11 m pos 281°·8, Δ R A = 20ˢ·0	382
739	I. 81	10 34 10·6	64 10 58	p B; L; g b M; has (?) a * excentric within it and a double * closely following it.	58
740	I. 26	10 34 33·3	77 7 19	e F; hardly visible	243
741	III. 842	10 34 45·7	33 9 7	p B; S; R; p g b M; 15″; a S * 90″ s	323
742	Nova.	10 34 53·0	58 22 58	e F; v S; very difficult, but a certain obs; is n of 2 st 9 or 10 m. Sky perfectly clear.	342
743	M. 95	10 34 54·5:	77 25 9:	v B; L; R; g m b M; 2′ diam. R A only approximate	19
		60·6	24 43	B; R; p g b M; r; 150″ diam	338
		62·2:	24 4	Just seen through a thick cloud	240
		...	26 ±	F; L; g m b M; r; 3′ diam. Approx place	243
		...	.....	Viewed; v F; E; r; 30 or 40″ (probably cloudy); a star precedes. A very doubtful obs.	2
744	III. 107	10 35 19·1	82 21 16	e F; R; b M; 30″; a * 9 m s dist 2′ or 3′	117
		19·2	21 34	F; S; R; b M; 20″	250
745	V. 52	10 35 20·5	25 53 1	p F; L; E in merid; g l b M; 2½′ l, 2′ br	411
746	III. 318	10 35 39·6	16 40 13	e F; L; R; v g b M; 60″; a coarse d * s f points back directly to it.	382
747	Nova.	10 37 26·8	87 19 7	e F; L; 2′ l, 20″ br; v g v l b M; a ray neb	144
748	II. 78	10 37 34·4	75 21 38	p B; v L; irreg R; v g b M; 2′ diam	338
		35·2	21 34	p B; L; R; v g b M; the preceding of 3 in a triangle. Pos of 1 and 2 = 68°·4; of 2 and 3 = 156°·8.	242
749	M. 96	10 37 42·4:	77 18 11	v B; L; R; g m b M; r; 2′ diam	19
		43·1	17 34	v B; p L; s m b M; almost to a nucl. Seen at the same time by M. Knorre.	22
		46·8	17 17	v F (cloudy); R; p s b M; a good obs of place	240
		48·5	17 0	v B; v L; E; v s v m b M; 6′ l, 5′ br	340

No.	Synonym.	R 1830·0.	N.P.D. 1830·0.	Description and Remarks.	Sweep.
		h m s	° ′ ″		
750	II. 81	10 37 57·9	71 50 1	B; R; pL; pgbM; 35″	334
		58·4	50 27	pB; R; bM; r	63
751	Nova.	10 38 1·7	75 18 59	F; R. The second of 3 in a triangle	242
752	III. 701	10 38 4·2	45 54 52	vF; S; R; 12″	248
753	Nova.	10 38 13·7	75 25 49	F; R; the last of 3 in a triangle	242
754	II. 99	10 38 40·5	75 6 49	vB; R; sbm to a *; 45″	418
		41·6	7 6	B; R; smbM; 30″. Sky clearing after clouds	241
		...	.....	vB; first Class; vsvmbM; 90″	419
755	II. 360	10 38 45·2	60 30 31	B; R; smbM; 30″	65
		46·7	30 42	pB; R; bm; 25″	343
		48·2	30 6	B; R; sbM; 30″	66
		48·7	30 34	F; S; R; bM	57
		49·7	29 52	No description	115
756	II. 565	10 38 49·0	54 24 24	F; R	51
		54·0	23 20	pB; L; R; vgbM; 90″	128
757	I. 17	10 38 50·1	76 31 33	vB; pL; R; psvmbM; 50″; r. The first of 3	338
		50·5	32 14::	vB; R. The first of 3	243
		50·7	31 24:	vB; L; R; psbM; 50″. (Seen also in Sweep 2.)	240
758	I. 18	10 39 16·7	76 28 54	vB; L; R; psbM; 40″. The second and most n of 3	240
		16·9	29 19	vB; R. The second of 3	243
		17·1	28 48	vB; R; psbM; 30″. (Seen also in Sweep 2.)	338
759	Nova.	10 39 21·4	84 6 31	vF; R	142
760	Nova.	10 39 21·5	84 10 34	eF; E	238
		22·9	11 16	pB; R; bM; 15″	142
761	II. 41	10 39 28·1	76 34 23	F; E; vglbM; the last of 3	338
		28·8	33 59	F; L; the following of 3	242
		30±	34 ±	barely visible; pL. Place estimated from the position with respect to the others.	243
		...	.....	vF; diluted; E in parallel; 15″	2
762	Nova.	10 39 29·0	84 8 34	Suspected nebula. Has a B * near	238
763	II. 881	10 39 33·5	23 19 13	eF; S; psbM; near some stars	412
764	II. 872	10 39 57·5	23 21 23	vF; L; lE; vgbM; 50″ l, 45″ br	412
765	I. 116	10 40 20·5	56 7 24	pB; S; E. The sp of two; dist ½ diam	51
		22·6	6 55	B; R; bM	128
		...	8 ±	The p of 2; pos of the other 20° n f, dist 80. The first is the brightest.	125
766	I. 117	10 40 24·2:	56 6 57	pB; S; E. The second and fainter of 2	51
		29·1	6 5	pB; E; is n f the nebula I. 116	128
		...	8 ±	The second and fainter of 2; pos 20° n f. Hazy. Place uncertain.	125
767	II. 335	10 40 57·1	15 25 6	pF; L; E; vgbM; 60″ l, 40″ br	382

No.	Synonym.	Æ 1830·0. h m s	N.P.D. 1830·0. ° ′ ″	Description and Remarks.	Sweep.
768	II. 361	10 41 22·2	60 38 17	pB; R; bM; 20″	343
		23·1	38 19	F; S; R	57
		23·4	38 11	pF; R	66
769	III. 919	10 41 23·8	27 43 38	eF; S; R; 6″	406
770	III. 913	10 41 27·5	30 40 17	vF; S; R; is 12″ n of 2 p b st forming an isosceles triangle. .	323
771	Nova.	10 41 29·0	38 4 23	pB; 2nd class; R; p g b M; among many stars	328
772	II. 718	10 41 48·4	45 23 22	B; S; R; the 2nd and northern of a trapez of stars 11 and 12 m	248
773	II. 362	10 41 53·5	61 7 8	B; R; g b M	68
		53·6	7 58	B; R; s m b M; 30″	65
		54·5	7 27	B; pL; R; p g m b M	343
		55·7	8 12	vB; R; v m b M; 60″	115
774	I. 27	10 41 53·9	75 41 13	B; R; v s m b M almost to a ✻; 30″	241
		54·9	41 30	B; R; p s b M; 50″; r	340
775	II. 363	10 42 1·5	60 59 27	F; L; R; b M	343
		3·4	59 58	pF; R; p s b M	415
		...	59 52	vF; S; g b M; 20″. Too late for R A	115
		...	59 44	vF; R; R A missed	57
776	III. 522	10 42 10±	101 57 ±	vF; R; b M. R A from working list	129
777	IV. 6 / III. 88 / II. 131	10 42 21·0	83 15 36	F; vL; irr R; v g b M; r; 2′ diam; no other seen. This neb is identical with III. 88 and II. 131.	250
		24·1	15 34	F; vL; R; v g b M; at least 4′ diam; no other near	117
		25·7	15 22	vL; R; 3′ diam; v g b M; r. Directing the eye aside, the stars in it were seen as infinitely minute points. In the 40-feet reflector it would no doubt be seen as a globular cluster.	251
778	II. 494	10 42 21·1	56 12 22	B; E in a wisp; the sp of 2	128
		...	13 ±	F; the sp of *three*. P D very rough	337
779	Nova.	10 42 47·1	56 8 40	B; L; E; g b M; the n f of 2	128
			7 ±	pB; p m E; the second of *three*. P D rough	337
780	I. 172	10 42 50·1	52 29 5	vF; a long ray pos = 40°·8; has a D class 4 *in middle*, and one more.	401
		57·1	28 52	pB; v m E; 90″ l, 12″ br; pos = 44°·2. Its *southern extremity touches* the L ✻ of a D ✻. Can this nebula have moved?	331
781	II. 887	10 42 58·9	27 48 51	eF; lE; S; v g b M; 15″	406
782	Nova or I. 118	10 43 ±	56 1 ±	B; L; the n f of three in a line. This neb may possibly be I. 118, as none exists in the place indicated by my Father (1°32′ s of 46 Ursæ).	337
783	III. 20	10 43 6·1	78 57 17	eF; vL; R; v g l b M; 2′ diam	120
784	III. 497	10 43 10·1	85 18 46	pB; R; v g l b M; 30″	142
785	III. 914	10 43 18·7	31 58 57	No description	323
786	II. 47	10 43 21·2	66 9 48	B; pL; E 30° n p to s f = pos 120°	59
		21·8	10 13	pB; lE; g b M	244
		...	10 8	pB; lE; b M; 40″. R A lost	246
787	I. 267	10 44 6·5	32 6 47	pB; L; R; v g l b M; has ✻ 10 m 2′ n f	323

No.	Synonym.	R 1830·0.	N.P.D. 1830·0.	Description and Remarks.	Sweep.
		h m s	° ′ ″		
788	I. 283	10 44 15·2	34 47 17	B; m E; g b M; no nucl; 1½′ l, 20″ br; pos = 67°·0	324
789	II. 364	10 44 56·0	61 51 22	p L; E; b M; 90″ l	115
		62·7	51 41	e F; R; 40″	65
		63·1	51 36	F; L; R; v l b M; 60″	66
		64·1	51 39	p B; S; R; b M	57
790	Nova.	10 45 24·8	71 45 1	p F; l E; the n p of two	334
791	II. 82	10 45 26·8	71 48 41	p B; E; g b M. The s f of 2; a * 9.10 m between them	334
		...	48 28	No R A observed	63
792	IV. 29	10 45 42·8	105 7 25	A * 12 m with an extremely F neb appendage. At first it seemed to envelope the *; but Mr. DUNLOP, to whom I showed it, considered it to be detached.	111
793	Nova.	10 45 45·6	71 29 22	Stellar. 2 or 3 stars with a nebulous burr observed by Mr. BAILY.	63
794	II. 16	10 46 28·0	81 24 9	v F; S; R; p s b M; 12″	250
795	Nova.	10 46 36·9	13 54 6	e F; p L; R; v g l b M; 30″; a D * n f points to it	413
		38·2	54 21	e F; a D * points to it	414
796	Nova.	10 47 23·3	79 21 15	v F: has another still fainter following; has also a * 9 m preceding in the same parallel.	120
797	III. 632	10 47 51·0	48 8 18	F; S; R; g b M; 15″	335
		51·2	8 50	not v F; S; R; p s b M; 12″; a * 13 m near	248
798	Nova.	10 47 51·8	79 20 15	v F; R; v s m b M to a * 12 m	120
799	II. 888	10 48 12·8	29 35 13	e F; R; v g b M; 15″	406
800	III. 332	10 49 12·2	64 51 43	v F; R; g b M; 2′ s of a * 13 m	407
801	III. 705	10 49 34·1	42 58 42	F; S; R	139
802	III. 967?	10 50 8·9	13 16 11	A very doubtful object	414
803	I. 269	10 50 59·7	31 25 17	e F; l E; 40″. It is n of a * 13 m, just at the edge of the neb	323
804	II. 100	10 51 0·9	74 16 54	F; L; R; g l b M; 85″	418
		3·1	14 15	p B; L; E; has a * 11 m 7ˢ·5 s p	419
		3·4	15 7	F; p L; 90″	24
805	I. 87	10 51 3·2	60 7 2	B; L; R; p s b M; 2′	343
		4·8	6 51	v B; v L; R; s m b M; 90″	65
		5·1	6 41	p B; v L; R; g b M; r	68
		5·4	6 28	v B; E; p s m b M; 60″ l, 40″ br	415
		5·6	7 4	No description	416
		5·7	7 9	F; L; b M; 50″	57
		6·0	6 44	p B; R; p g m b M; r	341
		6·0	6 56	v B; L; R; s b M; 90″	66
		6·2	6 11	B; L; R; g m b M; 50″; r. No doubt a distant globular cluster	342
		9·8	6 17	p B; R; r; seen through cloud	56
806	II. 101	10 51 21·0	75 11 28	v B; first class; l E; p s b M, r	338
		21·0	11 16	v B; first class; R; v s m b M, almost to * 11 m	241
807	III. 21	10 51 39·8	76 55 39	e F; R	242

No.	Synonym.	R 1830·0.	N.P.D. 1830·0.	Description and Remarks.	Sweep.
		h m s	° ′ ″		
808	Nova.	10 52 10·2	61 22 17	v F; R; b M	343
		12·9	61 22 52	e F; has a S * sp	115
809	III. 498	10 52 26·4	85 27 8	No description	143
		27·2	28 5	F; m E, 60° with merid; 60″ l; 15…20″ br	141
		28·2	28 26	e F; sky perfectly clear	142
810	I. 88	10 53 55·0	61 6 20	p B; E. Pos by diag 120° ±. Nucleus has stars in and about it	68
		55·1	7 7	B; E; v s v m b M, to nucl; many v S stars about it	343
		55·3	7 3	v B; a * 10 m with an E neb and a S * 25″ f	415
		55·7	6 36	B; p L; R; s m b M to a *; 60″; r; st seen	65
		57·4	7 20	p B; S; E; comes up to nucleus	57
		…	……	Viewed past merid. v B; E; s m b M; has a * f involved	115
		…	7 6	B; m E; comes up to a nucleus	66
811	III. 22	10 54 18·9	78 0 15	F; R; b M	340
		19·1	1 33	F; S; R; v g v l b M	120
		19·9	0 24	e F; R	242
812	IV. 7	10 54 22·4	70 56 52	a * 9 m with v F neb attached; pos 70° s p = 200°·0 ± dist 30″	63
		24·3	57 13	v F neb with a v F nucl; has * 10 m, n f dist ½ diam of n from edge; pos = 30°·0, and another sp of 10 m dist 3′.	334
813	II. 365	10 54 26·9	60 11 41	Has a * 7 m dist 8′ pos 40° n p	66
		29·1	12 52	p B; m E; nearly in merid; b M	115
814	II. 507	10 54 34·8	105 22 24	F; l E; b M; v L; involves a * 45° n f from the nucleus	111
815	Nova.	10 54 49·9	61 2 9	F; R; p g b M; 35″; sky dull	416
816	II. 336	10 54 53·8	16 30 42	A singular object. A burred star 11 m diam 12″; v s m b M; a D * follows.	382
817	II. 884	10 55 24·4	32 33 47	e F; R; 12″; v g l b M	323
818	I. 13	10 57 6·4	89 7 17	v B; L; m E (pos by diag = 140° ±); 4′ l, 1′ br; v s v m b M. The nucleus is rather excentric, being rather towards the s p side.	144
819	III. 23	10 57 39·0	77 41 28	p F; S; l E; s f a * 12 m	338
		39·1	41 44	v F; R; b M; has 2 st exactly in a line with centre (by diag n p), one 11.12 m, the other 13.14.	242
		39·4	41 50	not v F; E; p s b M; s f a * 11 m	340
820	III. 350	10 58 0·9	60 33 41	e F; has a * 10.11 m, 60″ p	66
		3·6	33 35	e F; a * 10 m precedes, and a D * points downwards (to s) between them.	68
		5·6	34 21	The faintest imaginable. Follows 1′ a * 11 m	65
		10·1	……	Follows a star. (Evidently a hurried obs.)	57
821	III. 915	10 58 32·3	31 51 47	e F; S; R; p g b M; 10″	323
822	Nova.	10 59 41·1	60 37 32	F; S; R; b M; 15…20″	115
823	III. 111	10 59 44·0	84 15 3	F; R; b M; sky perfectly clear	143
824	Nova.	10 59 52·6	53 3 2	p F; R; p s b M; 20″; a * 7 m p dist 7′…8′	331
825	Nova.	10 59 53·4	60 24 47	e F	343
826	III. 920	11 0 38·8	27 44 18	e F; S; 15″; appears hairy	406

No.	Synonym.	Æ 1830·0. h m s	N.P.D. 1830·0. ° ′ ″	Description and Remarks.	Sweep.
827	Nova.	11 1 1·4	53 2 52	e F; R; a * 8 m precedes	401
828	II. 42	11 1 4·8	78 21 15	F; S; l E; of nearly uniform brightness	120
829	III. 351	11 1 25·4	60 18 33	p B; has a * foll, dist 1′	415
		25·4	18 57	p F; R; 25″; the first of a group of 4	343
		25·8	20 22	v F; S; R	115
		26·3	19 4	F; S; R; b M; 20″, a B * follows, dist 1′	66
		27·4	18 31	B; S; precedes a * 9 m dist 1′. The first of a group	65
		34·9:	19 17	e F; 1′ preceding a * 9 m	68
830	II. 337	11 1 25·4	16 12 16	p F; l E; g b M; 20″; a * 15 m dist 70″; pos from neb = 22°·1	382
831	V. 46	11 1 26·4	33 25 0	B; v l; p b r; v m E; pos 79°·0. Has a distinct * in centre and 1 or 2 v S st elsewhere.	324
832	III. 352	11 1 29·4	60 24 37:	v F; the second of 4	343
		30·9	23 13	e F	415
		35·8	22 10	So excessively F as hardly to be discerned on long attention. The second of a group of 3.	65
833	Nova.	11 1 34·4	60 26 37:	e F; the third of a group of 4	343
		...	26 ±	F; R; b M; not v S; P D mistaken 10′; corrected	115
834	III. 79	11 1 51·9	77 53 50	F; R; g b M; 20″ (conspicuous). The P D of the working list is 6′ out, owing to which I have often before looked for it in vain.	340
835	Nova.	11 1 57·9	60 24 37	v F. The last of a group of 4	343
		58·3	22 11	F; p L; 8′ dist from another (III. 351) and 30° s f it	66
		59·4:	22 31:	e F; the last of 3	65
836	III. 89::	11 2 27·9	83 15 34	v F; wind furious; perhaps only F stars	251
		30·5	15 4	e F; R; s b M; with an appearance of stars	117
837	Nova::	11 4 24·8	105 2 ±	A doubtful object, but probably a nebula	111
838	M. 97	11 4 49·4	34 3 52	A large uniform nebulous disc, diameter 19″·0 of time in Æ. Quite round, v B; not sharply defined, but yet very suddenly fading away to darkness. A most extraordinary object. See fig 32.	324
839	III. 921	11 5 3·3	28 22 43	v F; L; v g v l b M; 45″; situated in the centre of gravity of a triangle of 3 large stars 5′ distance.	406
840	I. 29	11 5 39·2	76 16 23	B; E; p s m b M; 40″ l, 30″ br	22
		42·4	15 29	No description	242
		43·9	15 18	No description	338
		...	.....	v F; b M; E in parallel; 20″; viewed and only a rough place taken.	2
841	II. 102	11 6 9·2	74 17 14	No description	418
		...	17 0	p F; v L; g b M; 2′ diam	419
842	II. 709	11 6 26·4	47 28 42	p B; S; l E; v g b M; 20″	248
843	II. 49	11 6 29·0	70 57 56	B; R; p s m b M; 35″	334
844	III. 27	11 7 44·0	71 5 7	p F	63
		49·5	3 36	F; S; R; 12″	334

Fig. 32.

No.	Synonym.	Æ 1830·0.	N.P.D. 1830·0.	Description and Remarks.	Sweep.
		h m s	° ′ ″		
845	H. 50	11 7 54·0	71 2 12	vB; R	63
		57·0	1 31	vB; L; R; vmbM; 35″	334
846	H. 51	11 7 59·5	70 56 2	vB; R	63
		61·0	56 1	pB; pL; R; psbM; 30″	334
847	I. 270	11 8 21·5	30 17 43	vB; pS; lE; vsvmbM	406
		26·1	17 45	B; R; vsvmbM to a * 11 m	344
		27·7	17 35	pB; pS; R; psbM. Thick haze	226
848	I. 271	11 8 34·9	31 4 52	vB; mE; pos 305°·0, a nucl and F branches	323
849	H. 521	11 8 42·9	84 31 3	pB; R; psbM; 30″	143
		43·6	84 31 0	B; S; R; smbM; has a * 10 m, 60° np, dist 3′	141
850	H. 729	11 8 48·9	43 19 17	F; pL; glbM; r	139
851	III. 333	11 9 3·6	65 39 58	pF; smbM; stellar	407
852	H. 885?	11 9 24·0	31 20 22	pB; R; psmbM; 45″. The P D differs 7′ from that assigned by my Father; query therefore if the same object.	323
853	H. 879	11 9 40·4	21 49 43	pF; S; R; gbM; 15″	412
854	M. 65	11 10 1·0	75 59 16	B; R; gbM. Cloudy, but place well taken. (See fig 53.)	241
		2·4	58 54	F; L; E with a R nucleus; gbM; 4′ l	243
		4·1	58 44	aL, res centre with 2 F branches, E in a pos 45° np to sf	242
		...	60 12 : :	Place very rude. R; gbM; 20...30″. (It must have been very ill seen.)	3
855	Nova.	11 10 7·2	81 33 4	eF	117
856	H. 52	11 11 8·2	70 43 6	B; R; sbM; 20″	334
857	M. 66	11 11 16·9	76 5 47	vB; vL; sbM; 3′ l, 2′ br; E 60° np to sf in direction of 2 st 10 m, p.	22
		...	3 ±	pB; gbM; E towards 2 stars np	2
		...	5 32	F; gbM; E; has 2 stars np	3
858	I. 226	11 11 18·6	35 54 17	pB; L; R; smbM; 2′ diam	324
859	V. 8	11 11 22·4	75 27 42	A v long narrow ray vgbM; 15′ long, a most curious object. E by diag in pos 105°·0. (See fig 51.)	24
		22·4	28 55	pB; vLong; pos 100°·5; 6′ l, 1′ br; vgbm	340
		24·0	28 58	F; vL; vmE; vglbM; 8′ l, 2′ br; pos 103°·3	338
		24·1	28 59	pF; L; vmE, pos = 101°·0; vgbM; a ray	242
860	H. 338	11 11 25·0	62 5 52	F; pL	68
		26·2	6 47	F; L; R; vgbM; 2½′ diam	343
		26·5	6 11	F; L; bM; 2′ or 2½′ diam	66
		26·6	6 34	vF; R; vgbM; has * 14 m sf dist 60″	416
		27·0	6 32	not vB; vL; irreg R; vglbM	115
		28·4	5 53	vF; L; R; vglbM	415
		29·6	6 51	F; pL; R; has a small * sf	57
861	H. 32	11 11 32·3	86 6 30	B; R; smbM to nucl; 25″	141
		32·6	6 14	pB; R; bM almost to nucl	238

Fig. 53.

Fig. 51.

No.	Synonym.	R 1830·0.	N.P.D. 1830·0.	Description and Remarks.	Sweep.
		h m s	° ′ ″		
862	II. 550	11 11 50·8	99 20 42	F; v S; R; 10″	136
		51·1	21 9	p B; R; stellar; n p a ✱ 7 m	129
863	II. 551	11 12 5·1	99 19 29	p B; R; n f a ✱ 7 m	129
		5·3	18 44	F; v S; R; p s b M; 10″	136
864	II. 33	11 12 21·2	85 50 3	B; R; p s b M; 30″	143
		...	51 ±	B; R; p g b M; viewed past merid	238
865	I. 245	11 12 22·8	29 59 58	B; R; g b M; r; 45″	406
		24·6	59 14	v F; R; g b M; 30″	404
		24·7	60 22	p B; R; g b M; 40″; windy	344
		26·0	60 0	v F; R; g b M; haze thick	226
866	III. 15	11 12 45·2	68 54 30	F; L; E; 2′ long. The s p of two	59
		46·4	54 31	p F; v L; R; g b M; 60″; the p of 2	334
867	II. 32	11 12 48 ±	86 7 ±	p B; S; E; b M	143
868	Nova.	11 13 13·0:	49 12 46:	p B; p m E; S; has a suspicious nucleus, as if a v F close D ✱	335
869	III. 16	11 13 16·4:	68 52 1	v F; p L; R; g b M; 30″. R A estimated from that of III. 15.	334
		18·4:	51 46:	v F; S; R; the n f of 2	59
870	III. 335	11 13 25·7	64 46 13	F; R; g b M; the n p of 2	58
871	II. 775	11 13 28·4	51 17 59	F; p L; wires visible in twilight	73
872	III. 336	11 13 30·4	64 47 58	v F; the s f of 2	58
873	I. 5	11 13 57·6	72 28 1	p B; l E; g b M; 18″	421
		59·5	29 7	B; R; p s m b M; 35″	419
		59·8	28 49	B; R; p s b M; 25″....30″	418
874	II. 782	11 13 58·0	35 13 32	p B; R; v g l b M; 20″; a ✱ 12 m p	324
875	Nova.	11 14 11·5	76 5 3	v L; 6′ l, 4′ br; first v g, then v s v m b M	338
		...	.....	Viewed; v B; v L; v s b M. (See fig 54.)	340
876	III. 768	11 14 16·3	36 8 53	Not v F; v S; R. Approaching to stellar	328
877	IV. 59	11 14 45·1:	50 32 11:	F; R; about a stellar point 17 m	335
		...	.....	Viewed. Nothing remarkable in its character to place it in the 4th class.	73
878	II. 53	11 14 47·5	71 15 37	v F; R.	63
879	IV. 4	11 15 7·8	90 10 2	A star 13.14 m with a F, S, nebulous brush.	144
880	II. 845	11 15 26·9	25 37 11	F; R; g b M; 15″. A ✱ 9 m is 16ˢ p, 3′ n	411
881	I. 219	11 15 30·9	50 18 22	p B; R; p s b M; 45″	401
		33·3	19 16	v B; R; p g m b M; 50″; r. R 16ᵐ 33ˢ·3 by obs, but the minute must have been mistaken as my father makes it 15, with which Sw 401 agrees.	335
882	I. 20	11 15 37·0	77 44 8::	F; p L; p m E nearly in parallel. It precedes the ✱ 1341 A. S. C. 34ˢ·0. Pos with ✱ 234°·8.	338
		37·4	42 34	F; 2nd class; E in parallel	243
		38·4	43 49	e F; 2nd or 3rd class. The B ✱ 1341 A. S. C. follows it. This neb must have changed greatly if it ever belonged really to the 1st class.	242
883	II. 829	11 15 40·5	31 21 2	v F; m E; v l b M; 60″ l	323

Fig 54.

No.	Synonym.	Æ 1830·0. h m s	N.P.D. 1830·0. ° ′ ″	Description and Remarks.	Sweep.
884	III. 337	11 15 49·7	65 6 43	e F; v S; R	407
885	III. 922	11 16 9·1	28 35 18	This must be my father's neb, but it is a suspicious object, and I doubt whether it be not a little knot of 3 or 4 stars.	406
886	I. 131	11 16 27·3	98 52 ±	p B; p L; E in merid.	136
		...	51 55	F; L; E in direction of merid	129
887	I. 194	11 16 46·8	45 28 33	Seen through thick cloud	249
		48·0	28 47	v B; L; m E; v s m b M; 2′ l, 40″ br. Many stars 14 & 15 m precede.	248
888	Nova.	11 16 53·7	42 4 57	S; R; v s b M to a * 16 m	139
		55·7	4 12	e F; v s b m to * 16 m; 2 st 11 m, n f, point to it at twice their distance.	330
889	Nova.	11 17 11·7	61 11 52	v F; R; p s b M; 25″. Is 2′ s p a * 12 m	343
890	I. 262	11 17 30·8	22 28 41	p B; R; v s m b M almost to a *; 30″	412
891	II. 159	11 17 34·6	72 12 20	v B; R; p s b M; 40″; has st foll	419
		34·7	12 21	p F; R; g b M; 20...25″	421
		35·3	12 19	v B; R; p s b M; 50....60″	418
892	I. 246	11 17 49·9	32 11 5	E; haze so that I can barely be certain that a nebula exists	226
893	Nova.	11 18 16·0	72 1 46	p F; R; g b M; 25″	421
		20·5	3 41	c B; L; E; v g b M; 100″ diam	334
		...	1 54	p F; R; g b M; 45″; Æ observed 3ˢ·6, but was taken past merid by comparison with a distant star, by a process liable to great errors.	418
894	II. 160 } III. 28 }	11 18 49·2	71 51 7	B; L; R; b M; has a L * n and a smaller one s	63
		49·8	50 36	B; v L; E; v g b M; 2′ diam. Near a *	334
		...	50 0	p B; p L. (N.B. II. 160 and III. 28 are probably identical.)	61
895	II. 770	11 18 53·7	59 32 51	F; R; 30″	64
		55·3	33 11	B; L; R; r	66
		56·8	32 27	p B; R; 40...50″	68
		57·4	33 4	Not v F; R; g b M; 25″	341
		57·8	33 21	p B; R; s b M; 30...40″	65
896	I. 147	11 19 1·6	30 31 52	B; R; p g b M. Query whether there be not a * excentric towards the s f side. (N.B. The obs makes P D = 31°, &c., but this must be a mistake. See next obs and my Father's place.)	323
		...	29 55	F; S; R; b M; has a * near, s	226
897	II. 339	11 19 10·2	63 24 43	B; p L; g b M; 1 E	58
898	II. 54	11 19 14·8	72 8 39	No description	418
		15·7	8 55	F; E; 40″; has a * 10 m 5′ s p	419
899	Nova.	11 19 45·9	53 38 47	Not v F; R; s b M almost to a *; 20″	331
900	Nova.	11 19 55·3	68 15 58	e F; v S; E in parallel	59
901	II. 349	11 20 30·2	64 57 58	p B; 1 E	407
902	II. 13	11 21 20·4	79 47 10	F; p L; v s b M; haze troublesome	123
903	Nova.	11 21 27 ±	79 42 25	p B; S; E in parallel; 40″ l. Taken for II. 13, and the Æ set down from the working list, being missed. But it appears to be a different nebula.	120

No.	Synonym.	$\mathcal{R}$ 1830·0.	N.P.D. 1830·0.	Description and Remarks.	Sweep.
		h m s	° ′ ″		
904	II. 350	11 22 8·9	66 17 45	F; has a * 7.8 m n f dist 5′	244
905	Nova.	11 22 39·6	60 34 11	vF; R; s m b M	64
		...	36 ±	F; v S; R; b M. Rough P D, being past meridian.	68
906	II. 367	11 22 41·0	60 54 13	No description	68
		41·7	54 6	F; R; s b M. No companion seen	66
		42·2	55 7	S; R; s b M, almost to a nucleus	57
907	III. 353	11 22 52·2	60 42 27	F; S; R; 12″; no other near on the same parallel	343
		53·6	42 19	Not v F; R; p s b M; 15″	416
		53·7	41 32	Not v F; S; R; p s b M; 20″	417
		...	43 ±	Rough P D, being much past merid	115
908	I. 221	11 23 5·5	35 59 58	F; v L; R; v g l b M; 2′ diam; near a double star	328
		6·7	58 57	p B; v L; l E; v g b M; 5′ diam; has a coarse double * s p	324
909	II. 836	11 23 59·3	27 10 51	Not v F; R; g b M; 40″	406
		60·4	12 22	e F, but sky not perfectly clear. The obs makes the $\mathcal{R}$ 23^m 0·4, but it is clear from the former obs and my father's, which agree, that it should be 24^m 0^s·4.	344
910	II. 730	11 24 5·6	42 1 36	p B; v L; E in merid; v g b M; 4′ l, 2′ br; has a * at its northern extremity.	329
		6·4	0 27	p B; v L; l E; at first v g and then v s b M to a * 15 m. 2′ l, 90″ br; a * 11 m to n.	330
911	I. 222	11 24 22·3	35 55 52	Not B; L; l E; a * 12 m s p very near the edge	324
912	II. 351	11 24 27·2	64 37 3	F; S; R; b M	58
913	II. 552	11 25 36·1	98 54 4	S; R; p s b M; 15″; has a * 14 m, 45° s p	129
		37·3	53 38	F; R; b M; has a * 14 m s p	136
914	I. 287	11 25 56·3	18 31 37	F; m E, in pos 130°·4; b M; 90″ l, 12″ br	377
915	III. 847	11 26 42·2	29 5 18	v F; R; v g b M; 20″	406
916	Nova.	11 26 56·0	43 46 27	v F; R; v g b M; 20″	139
917	III. 905	11 27 9·7	13 47 1	e F	414
918	II. 784	11 27 24·9	34 45 47	F; L; l E; 4′ diam; brighter and larger than I. 222	324
919	III. 843	11 27 27·7	30 39 22	v F; R; 15″. Has a v S * s f rather more than a diameter from edge (by diagram).	323
920	Nova.	11 27 28·6	52 39 7	e F; p m E; p L; g b M	331
921	II. 837	11 27 47·7	27 19 5	e F; R; g b M; sky not quite clear	344
922	Nova.	11 28 7·4	64 57 30	v F; R; 30″	407
923	III. 29	11 28 21·0	71 13 52	Stellar; a burred star	63
924	Nova.	11 28 22·0	72 10 41	v F; S; b M	334
925	II. 731	11 28 30·9	41 9 16	B; S; m E; p g b M; 30″ l	329
		33·2	9 2	p B; m E; g b M; 60″ l, 30″ br	330
926	II. 338	11 28 31·6	29 27 3	B; R; g b M; r; 30″	406
		32·7	26 18	e F, but a sure obs. Sky growing dull. Mirror tarnished	404
927	II. 352	11 28 52·5	66 22 45	e F; E	244
		54·7	22 30	v F; S	59

No.	Synonym.	Æ 1830·0.	N.P.D. 1830·0.	Description and Remarks.	Sweep.
		h m s	° ′ ″		
928	III. 81	11 29 25·1	76 56 39	F; S; R; b M	242
		28·0:	56 55:	p F; R; p s b M. The only object in the sweep. The place reduced by the obs of the preceding and following sweep, ∴ precarious.	339
929	I. 227	11 30 0·8	32 47 37	F; L; R; v g b M; 60″. (Twilight.)	345
		3·6	47 22	e F; L; v g l b M; 90″	323
930	II. 732	11 30 24·7	42 35 37	A * 15 m with a nebulous tail n f which touches another star.	139
931	Nova.	11 30 42·9	57 9 12	p B; p m E; p g b M; 50″ l, 30″ br. The first of 2	342
		43·3	8 41	The s p of 2; less B and smaller than the n f	74
		44·6	8 35	B; p L; E; g b M; 40 or 50″ l	337
932	Nova.	11 30 45·9	57 7 22	p B; m E; p g b M; 90″ l, 40″ br; the second of 2.	342
		46·3	7 31	p B; E in merid; g b M; 40 ... 50″ l; the n f of two.	74
		47·6	7 15	B; p L; p m E; 50 ... 60″ l; 40″ br	337
933	III. 109	11 30 55·2	71 22 1:	The first of 3	61
		56·2	20 16	F; v S; p m E; s b M; the first of 3	334
934	Nova.	11 30 59·6	73 43 45	F; R; the preceding of 2; has 3 st s	419
		80·8	43 54	F; R; forms an appendage to II. 103, which it precedes. One or other of these right ascensions has some mistake, which pervades the observations of both nebulæ. (See below.)	418
935	III. 609	11 31 3·8	98 25 17	v F; R; g b M; 20″; has a * 8 m 6′ s, on same merid	136
936	II. 103	11 31 4·1	73 42 55	F; m E; g b M; the f of 2. This and the next Æ are probably affected by the mistake above noticed.	419
		8·8:	42 26	p F; p L; l E; g b M; near a B st	421
		23·5	42 49	F; E n f to s p; has another F neb attached to its preceding extremity. (See fig 79.)	24
		24·8	42 39	p B; E; p g b M; has another s p.	418
		24·9	42 29	p B or not v F; l E; g l b M	422
937	II. 839	11 31 4·7	28 46 16	v F; p s b M; by obs Æ = 30ᵐ 4ˢ·7; but this is proved to be erroneous by the coincidence of Sw 406 with my father's Æ.	344
		10·3	46 18	p B; R; 35″; p g b M	406
938	II. 340	11 31 20·2	64 21 38	p B; S; R; r; 20″	58
939	II. 161	11 31 25·4	71 20 17	p B	63
		27·2	19 18	The second of 3	61
		27·6	19 51	p B; p L; g b M; the second of 3	334
940	III. 30	11 31 30·1	71 17 26	The last of 3	61
		31·6	17 51	The last of 3	334
		32·3	20 38	An obs snatched between clouds and probably a mistaken bisection in P D.	62
941	III. 375	11 31 52·2	68 43 12	Not v F; S; R; b M	59
942	II. 737	11 32 7·5	41 21 6	F; R; b M; 15″	329
		9·6	20 32	F; E; g b M; 20″	330

Fig. 79.

No.	Synonym.	Æ 1830·0.	N.P.D. 1830·0.	Description and Remarks.	Sweep.
		h m s	° ′ ″		
943	I. 21	11 32 12·4	77 35 9	No description	242
		12·5	35 5	No description	340
		12·9	35 24	p B; L; 1 E; v g b M; 3′ diam	238
		...	35 12	F; R; g b M; 30...40″; the Æ of this sweep and both the Æ and P D of the next obs too roughly determined to be set down.	3
		...	.....	v F; R; v g b M; a ✱ 9 m 15′ dist in parallel	2
944	III. 320	11 32 14·0	64 14 13	F; R; has a ✱ 6.7 m s f, dist 3′	407
945	I. 94	11 32 17·1	52 29 46	p B; p L; 90″ l, 60″ br; E in parallel; hazy	72
		18·1	31 2	B; p L; 1 E; 40″ l, 30″ br; v g l b M	331
		18·5	30 31	v B; L; m E nearly in parallel; 3′ long; m b M; a ✱ f	70
946	III. 329	11 32 46·0	64 15 33	Not v F; p L; 30″	407
947	Nova.	11 33 7·4	78 45 45	F. The first of 4	120
948	III. 284	11 33 15·9	95 13 16	B; R; p s b M; 30″. At least 2nd class	147
949	III. 376	11 33 18·3	68 43 47	v F; S; R; p s b M; a ✱ 11 m prec 10ˢ·0	246
		19·2	45 10	Not v F; S; R; g b M	59
950	Nova.	11 33 18·9	78 44 45	v F; the second of 4; place estimated from the others	120
951	II. 153	11 33 25·4	78 47 15	p B; the third of 4	120
952	III. 774	11 33 32·5	36 16 53	v F; p m E	328
953	II. 154	11 33 38·4	78 48 5	p B; the last of 4	120
954	II. 341	11 33 39·7	62 34 17	No description	343
		39·9	33 35	p B; R; p s b M; 15″. Good obs.	417
		40·8	34 17	No description	115
955	III. 775	11 34 13·7	36 19 53:	e F	328
956	Nova.	11 34 22·3	62 33 34	Cloudy; hardly discernible	416
957	Nova.	11 34 40·3	101 55 24	F; v S; R; b M. Well observed	129
958	Nova.	11 34 44·0	28 57 0	p F; 1 E; g b M; precedes ✱ 8 m, 5′ dist	344
		46·3	56 38	p B; p m E; p g b M; has a D ✱ 8 m, n f	406
959	II. 831	11 34 49·5	31 5 50	v F; p m E; p s b M to nucl = ✱ 12 m. Twilight	345
		51·7	6 57	B; S; a nucleus with an extended burr; 15″ long. P D by Sw 32°, corrected to 31, which is the true degree.	323
960	Nova.	11 34 56·4	69 5 47	F; R	63
		61·6	6 1	v F; S; the first of 4	334
961	Nova.	11 35 3·4	69 10 27	F; R	63
		7·6	10 0	v F; p S	334
962	III. 377	11 35 8·1	69 6 41	p B; v g b M; the third of 4	334
		10·4	8 7	p B; R; the last of 3	63
		13·2	6 57	v F; R; the s p of two	59
963	Nova.	11 35 13·1	69 4 11	v F; p S; the last of 4. There are however 3 or 4 more nebulæ in this neighbourhood.	334
964	Nova.	11 35 15·4	33 24 42	F; p L; R; v g b M	324
965	Nova.	11 35 18·8	55 32 20	Not v F; S; R; p s b M	337

No.	Synonym.	Æ 1830·0. h m s	N.P.D. 1830·0. ° ′ ″	Description and Remarks.	Sweep.
966	III. 378	11 35 32·7	69 5 35	vF; R; the n f of 2	59
967	Nova.	11 36 ±	55 57 ±	eF; R; g b M. The preceding of 3 forming an equilateral triangle. Place very rough.	337
968	Nova.	11 36 ±	55 54 0	eF; R; g b M. The second of 3	337
969	Nova.	11 36 ±	55 57 ±	eF; R; g b M. The last of 3	337
970	Nova.	11 36 12·2	69 4 21	F; S; R; b M. Doubtful	61
971	Nova.	11 36 54·8	78 14 2	F; S; s b M; irreg fig; r	19
		59·9	13 52	F; R; p s b M	22
972	III. 833	11 36 55·0	38 51 13	vF; a doubtful object. Query if not a D * 6″ dist involved in a nebula.	328
		57·6	51 31	F; S; R; p s b M	329
		60·9	51 17	Foggy	330
973	II. 104	11 37 1·1	75 17 0	B; S; R; p s b M; 10″	419
		2·9	17 49	B; R; v s m b M, to a * 11 m; 40″	242
		3·4	17 51	pB; S; R; s m b M; 15″; compact	338
974	Nova.	11 37 21·9:	55 51 21:	vF; R; the first in an unequally divided line of 3. More suspected.	74
975	Nova.	11 37 26·9	55 53 21	vF; R; b M; the second of an unequally divided line of 3	74
976	Nova.	11 37 40·4	55 57 6	vF; R; the third of an unequally divided line of 3	74
977	Nova.	11 37 57·4	68 39 40	pF; n f a * 7 m; Δ Æ = 4ˢ·5; dist 5′	409
		60±	40 49:	vF; R; g b M. (Taken past merid. Æ estimated. P D too great.)	59
978	II. 785	11 38 27·0	33 5 17	pB; E; g b M	323
		31·5	5 32	pB; lE; p g b M. Twilight	345
979	I. 120	11 38 27·1	105 54 55	F; L; has * 11 m 5ˢ· n f. Twilight	149
980	II. 723	11 39 11·1	58 41 51	B; R; s b M; 20…30″	65
		11·5	41 19	eF. Seen through cloud	341
		11·5	41 24	not vF; R; g b M; 40″	342
981	II. 553	11 39 22·0	100 0 35	L; R; g b M; 60″; r	129
982	II. 738	11 39 37·1	40 20 26	B; pL; R; g b and p s m b M; 60′	329
983	I. 248	11 39 40·7	29 38 36	B; pL; R; p g m b M; the prec of 2	406
		41·6	38 50	F; R; g b M; 20″	344
984	II. 832	11 39 52·3	29 37 51	F; pL; E; g b M. The foll of 2	406
985	I. 228	11 40 5·1	32 59 5	B; R; s m b M; 30″; hazy	346
		6·1	57 45	B; pL; R. Seen through thick haze	226
		11·2	58 22	pB; E; g b M; like II. 785, but brighter	323
		13·1	58 32	B; pL; R; p s m b M; 60″	345
986	II. 408	11 40 6·6	54 1 47	pF; R	331
		6·9	0 48	F; S; R; near a small *	72
		8·0	2 11	F; S; R; b M	70
987	Nova.	11 40 17·8	62 36 31	pB; R; s m b M	64

No.	Synonym.	Æ 1830·0.	N.P.D. 1830·0.	Description and Remarks.	Sweep.
		h m s	° ′ ″		
988	I. 82	11 40 19·0	62 2 1	B; L; R; p g b M; fading away to nothing; 40″ diam	65
		19·2	1 34	R; b M to nucleus; ☾ and haze	67
		19·4	1 13	p F; s b M; ☾☾	415
		19·9	2 7	B; p L; R; s b M to nucleus; 40″	57
		20·3	1 41	B; R; s b M; 40″	66
		...	2 39±	a L and B neb. Imperfect obs past mer	68
989	III. 321	11 40 26·7	62 56 28	F; p L; E; v l b M	58
		28·4	55 12	p F; l E; v g b M; 25″	417
990	Nova.	11 40 47·8	90 9 7	e F; S; p s b M	146
991	III. 341	11 41 15±	64 7 48:	v F; p L; Æ by working list; past mer	407
992	II. 342	11 41 15·1	62 33 50	p B; R; p s b M; 30″	417
		15·2	34 49	p B; p L; R; g b M; 60″	343
		15·9	33 20	v F; R; p s b M; ☾	415
993	II. 787	11 41 44·1	33 54 32	e F; R; g b M	324
994	II. 824	11 41 44·7	37 13 43	F; v m E; v g b M; 150″ l, 30″ br	328
995	III. 90	11 41 45·2	82 29 7	F; R; 15″; has * 13 m, 70″ dist, n p	253
		50·9::	28 39:	F; R; near a * 13 m. Wind outrageous	251
		...	29 ±	F; R; b M; 1′ s of a * 9.10 m	117
996	Nova.	11 42 0±	64 7 48	No desc. Follows III. 341 on same parallel	407
997	II. 788	11 42 1·0	33 58 32	p B; R; p s b M	324
998	III. 379	11 42 38·0	67 2 20	e F; R; S; near a star	244
999	II. 740	11 42 49·6	40 21 56	not v F; S; R; p s p m b M	329
1000	III. 616	11 42 53·0:	51 3 24:	e F; g l b M; a * 7 m foll nearly in the parallel	335
		58·1:	3 17:	e F; precedes a * 7 m in the same parallel, dist about 3′. Place uncertain.	331
1001	Nova.	11 43 33·1	56 39 1	p B; R; p s b M	74
		35·6	39 13	p B; S; p m E; p s b M	337
		36·8	38 17	F; R; p s b M; 20″	131
1002	I. 203	11 43 54·4	44 56 2	A superb nebula; B; v L; R; 3′ diam; v g b M; r; is probably a globular cluster.	248
		57·7	55 7	p B; v L; R; v s b M to a v S star, and very dilute at the borders; 4′ diam.	139
1003	III. 389	11 43 55·8	68 25 6	v F; S; R	423
1004	Nova.	11 44 1·2	68 4 0	e F; R	59
1005	I. 173	11 44 3·5	52 3 19	v B; p L; R; p s m b M	73
		3·9	3 1	v B; R; s b M, fading to nothing; 90″	72
		5·5	5 11	v B; R; s m b M, almost to a * 9 m; 60″	70
1006	I. 251	11 44 11·8	28 23 3	not v B; R; p g b M; r	406
		16·5	23 25	B; R; p s b M; 60″; a star precedes, Δ Æ = 8ˢ·0, pos from neb = 215°·9.	344

No.	Synonym.	R 1830·0.	N.P.D. 1830·0.	Description and Remarks.	Sweep.
		h m s	° ′ ″		
1007	III. 322	11 44 16·2	62 50 49	Not v F; R; s b M; 35″	343
		17·3	50 52	p B; R; b M	115
		17·4	50 17	B; R; p s b M; 35″	417
1008	II. 403	11 44 34·9	68 18 0	F; m E; b M; a coarse D ✱ precedes	409
		...	18 ±	Seen in its place as per working list	244
1009	I. 202	11 44 46·9	41 12 46	B; m E; v g b M	329
		47·2	11 12	p L; R; g b M; barely visible for fog	330
1010	III. 342	11 44 49·2	65 39 28	v F; S; R	407
1011	V. 45	11 44 52·3	36 43 3	B; L; v s b M; r; 3′ diam. Fine object	328
1012	III. 612	11 44 55·2	93 3 9	p F; R; b M	21
		57·0	3 36	F; 1 E; nearly in parallel r::. Sky perfectly clear	147
		...	4 17::	v F; 1 E. Sky not quite clear; P D rough, being taken beyond meridian.	146
1013	Nova.	11 44 57·0	68 10 44	e F; R	59
1014	II. 833	11 45 23·6	30 41 7	p F; 1 E; g b M; 40″ l	345
		28·7	41 32	p F; E; v g b M; 60″ l	323
1015	IV. 67	11 45 50·2	30 34 7	F; v L; R; p g l b M	323
		54·6	33 35	F; L; R ill defined nebulous mass; obs difficult, owing to haze	226
1016	Nova.	11 46 5·2	60 47 41	v F; E 45 s p from a ✱ 10 m dist 40″	66
		6·7	46 21	A ✱ 10 m with e F neb 45° s p; 30″. The neb by a diag made at the time is oval, and forms a kind of appendage to the star.	65
		...	47 22	F; R; near a ✱	417
1017	IV. 62	11 46 31·5	33 56 0	B; p L; R; nearly uniform, but hazy; diam 25″	324
1018	II. 162	11 46 42·9	77 5 14	p B; R; v g b M; a ✱ 10 m 25° n f, dist 4′..5′	242
		44·9	5 18	p B; L; p s m b M; 3′ diam	338
1019	II. 724	11 46 46·7	59 3 39	p B; R; b M. An exact obs.	67
1020	Nova.	11 46 47·1	101 5 54	F; S; R; p s b M; 15″. The p of 2	129
1021	Nova.	11 47 0·6	101 2 44	v F; S; R; b M; 15″. The f of 2	129
1022	II. 132	11 47 12·6	82 18 19	B; E 30° n f to s p; v s m b M to nearly a star. The arms very faint.	117
		13·8	17 29	B; E; p s b M; 25″ l, 15″ br	251
		14·2	18 21	v B; m E; v s m b M; 30″ l; nucleus equals a star 10 m	250
1023	II. 840	11 47 18·6	28 32 8	Not v F; 1 E; has ✱ 8 m following in the parallel	406
		20·7	32 50	v F; a ✱ 9 m f, dist 6′; another precedes 10′ dist to the s	344
1024	III. 343	11 47 37·2	65 10 54	F; S; R; p s b M	407
1025	III. 707	11 47 49·6	40 42 56	No description	329
1026	Nova.	11 47 50·2	60 3 25	e F; R; b M; 25″. Supposed at the time to be II. 724, but on reducing the obs it differs 1ᵐ in *R* and 1° in P D, *both* which can hardly be mistakes.	342
1027	Nova.	11 47 56·5	57 1 32	F; S; E; near a ✱	131
		57·3	2 21	E nearly in parallel; a ✱ 11 m near	74
		57·5	2 0	p B; m E; p s b M; 30″ l; near a ✱	337

No.	Synonym.	Æ 1850·0. h m s	N.P.D. 1850·0. ° ′ ″	Description and Remarks.	Sweep.
1028	Nova.	11 48 36·6	61 10 42	v F; R; g b M. The first of 2	343
		...	10 42	v F; S; R; s b M like a ✻. The p of 2 with several stars between them.	417
1029	II. 791	11 48 39·9	33 36 30	v F; R; p s l b M; 35″; sky dull	346
1030	IV. 61	11 48 41·3	35 40 33	v B; v L; R; s m b M; 3′ diam	328
1031	I. 229	11 48 59·9	33 36 20	B; R; s m b M; 40″; sky dull	346
1032	Nova.	11 49 0·6	74 45 10	v F; p L; R; has two st s f	419
		1·9	43 29	No description, (probably a hurried obs)	422
		2·2	45 46	No description	421
1033	III. 323	11 49 3·2	63 47 33	F; v S; E pos 25° n f to s p. Between two stars, 80″ dist. (By a diagram made at the time, the neb lies exactly in the line of the two stars which are situated at equal distances from the two extremities, and almost in contact with them. A singular object.)	58
1034	III. 344	11 49 12·8	65 50 38	v F; R; the northern of 2	407
1035	III. 345	11 49 12·8	65 54 58	v F; R; the southern of 2	407
1036	Nova.	11 49 19·4	61 10 42	v F; R; near a ✻ 12 m	417
		20·6	10 0	p F; l E; g b M; the f of 2 in parallel, with a star between	343
1037	Nova.	11 49 24·2	91 11 7	F; S; R; b M; s p a ✻ 11 m	146
1038	II. 368	11 49 29·7	60 51 26	F; S; R; b M	64
		29·7	52 1:	v B; p L; R; s m b M; 40″. Clouded suddenly, and obs left imperfect.	65
		30·1	51 36	p B; R; s b M	66
		31·0	51 34	p B; R; g b M; r	68
1039	Nova.	11 49 31·7	.....	v B; m E; m b M. Taken for II. 368, and no P D taken; but the description disagrees essentially, and it can hardly be the same.	115
1040	Nova.	11 49 40·8	41 49 9	F; m E; v g l b M; 100″ l, 25″ br	255
1041	II. 733	11 49 42·3	45 6 17	B; m E; v s v m b M to a ✻ = 10.11 m; pos of extension = 62°·3 by measure.	248
		49·0	8 ±	A ✻ 11 m with a strong nebulous ray (25° n f to s p by estim from diagram); v s v m b M.	140
1042	III. 3	11 49 51·5	72 52 48	Not v F; R; p g b M; 35″	421
		53·0:	52 14	p B; p s b M; 25″	422
1043	III. 369	11 50 7±	61 34 52:	p B; L; g b M. Æ by working list; past merid	68
		...	34 46:	v F; L; 60″; past merid	66
		...	36 ±	Seen; no descrip. P D very rough	115
1044	Nova.	11 50 10·3	74 50 45	e F; has a ✻ 9 m 5′ s f	419
1045	II. 275	11 50 11·0	58 37 56	Not v F; bicentral or elongated; v g b M, to a central axis pos = 199°·5, or pos of the two centres = 19°·5; 14″ l, 25″ br	342
1046	III. 617	11 50 24·6	51 14 38	e F; p L; R	73
1047	I. 223	11 50 33·1	38 5 43	No description	328
1048	I. 121	11 51 39·8	90 9 32	B; R; 60″; a ✻ 10 m, 50° n p	146
		40·3	8 40	B; R; p L; p s b M; r; 70″; has 3 or 4 large stars near	145

No.	Synonym.	R 1830·0.	N.P.D. 1830·0.	Description and Remarks.	Sweep.
		h m s	° ′ ″		
1049	II. 404	11 51 46·9	68 59 27	B; p L; R; b M	63
		46·9	58 16	B; p L; R; b M	61
		48·7	58 14	e F; L; v l b M; a ✱ 12 m, n f	246
		49·3	58 11	p B; R; g b M; 40″	423
		49·4	58 20	p B; p L; R; g b M	409
		50·0	58 50	v F	244
1050	I. 253	11 52 38·6	27 9 58	p B; R; p s l b M; 25″	344
1051	III. 77	11 52 39·6	75 39 9	e F; R; a ✱ 16 m, n f (pos = 80°·0,) dist 2′	242
		41·9	39 15	e F; L; R; v g v l b M; 2′ diam; 21ˢ·0 of time preceding a ✱ 8 m.	338
1052	IV. 28. 1	11 53 11·8	107 55 10	v L; R; v g b M; the chief neb of a fine double nebula. The other is 2′ s. They run together.	149
1053	IV. 28. 2	11 53 11·8	107 57 10	The northern of the double neb. It is the smaller and fainter of the two.	149
1054	I. 252	11 53 25·0	26 55 26	p B; R; g b M; 35″; sky not quite clear	344
		25·2	54 51	B; R; at first g, then p s v m b M to a nuclear mass which seems resolvable.	411
1055	Nova.	11 53 28·9:	84 42 ±	S; R; precedes a double ✱ about 30ˢ, and is 3′ south of it. R a rough estimate only from the double ✱.	142
		38·7	43 15	Not B; S; R; p s b M; 15″	143
1056	III. 491	11 53 46·7	89 15 52	F; v S; R; b M	145
1057	II. 276	11 54 0·7	87 4 47	F; R; s b M; 25″; a ✱ s f	141
1058	II. 741	11 54 3·6	40 25 6	B; p L; R; p g b M; 40″	329
1059	Nova.	11 54 5·6	71 2 1	v F; S	61
		7·3	2 21	v F; S; R; p s b M; almost stellar	334
1060	III. 390	11 54 9·4	70 18 42	v F; S; l b M	63
		...	18 16	v F; p L; R; g b M	334
		...	18 1	e F; S; too late for transit	61
1061	IV. 56	11 54 24·5	44 31 9	E; pos of axis 132°·0; a ✱ 11.12 m, dist 2′, pos 257°·0	256
		24·8	31 7	p F; v L; E; at first v g l b, and then v s v m b M, to a ✱ 14 m. A ✱ is s p.	255
		25·6	30 59	p B; L; E; 3½′ l, 2¾′ br; at first v g l b, but then suddenly comes up to a ✱ in centre = 11 m.	138
		27·5	30 52	E; L; v s m b M to a ✱ 11 or 12 m; has a ✱ 10 m 20° s p	139
1062	Nova?	11 54 59·8:	68 ±	p B	423
1063	Nova?	11 55 4·3:	68 ±	p B	423
1064	Nova?	11 55 8·3:	68 ±	p B. On merid with two more	423
1065	III. 394	11 55 18·8	68 49 29	e F; double neb, both S; R; pos 20° n f	246
		19·1	49 0	v F; a double neb by diag, pos 20° s p, nearly equal. They run together.	244
		19·4	50 24	v F. The first of 5	59
1066	I. 174	11 55 17·5	57 9 27	B; v L; m E; pos = 97°; g b M; 6′ long	342
		19·6	9 31	p B; v L; E in parallel; 3 or 4′ l, 90″ br	74
		20·4	9 45	F; v L; v g b M; m E in parallel; 4′ l, 2′ br	337
		25·5	9 22	p B; v L; m E; 10° n p to s f; v g b M; 3′ l, 1′ br	131

No.	Synonym.	R 1830·0.	N.P.D. 1830·0.	Description and Remarks.	Sweep.
		h m s	° ′ ″		
1067	III. 395	11 55 24·9	68 49 30	p B	409
		25·4	50 24	v F; R; the second of 5	59
1068	III. 391	11 55 25·8	68 41 51	No description	423
		27·1	42 5	Not very F. Another seen	424
		27·4	42 0	p B	409
		29·4	41 37	The third of 5	59
1069	III. 37	11 55 27·6	78 12 11	F; R; b M; 30″	19
		27·9	11 26	v F; L; p g b M; 2′	338
		29·1	11 57	F; R; v g b M; 15″; good obs.	242
		29·1	11 50	p B; R; b M; 40″	120
		30·1	11 58	F; R; b M	22
1070	III. 392	11 55 29·4	68 43 37	v F; R; the fourth of 5; has another on the same meridian, n	59
1071	Nova.	11 55 29·4	68 38 30	p B	409
		30·1	39 55 : :	Not v F	424
1072	II. 277	11 55 43·7	87 9 17	Not v F; R; g b M	145
		45·3	9 13	F; R; b M; 15″	143
		45·5	9 54	p B; L; R; p s b M; 60″	238
		45·6	9 15	p F; irr R; p s b M; 40″	141
1073	III. 394	11 55 48·5	68 44 0	e F	409
1074	Nova.	11 55 48·7	86 59 7	F; S; R	145
1075	III. 396	11 55 52·4	68 53 30	The last of 5	59
1076	III. 258	11 55 57·3	87 16 3	F; R; b M; 20″; the s f of two	143
1077	Nova.	11 56 5·9	91 26 7	Not v F; L; R; 40″; has a * 10 m, 60″ n	146
1078	III. 355	11 56 8·9	62 3 16	e F	66
		9·3	3 14	F; R; g b M	68
		10·0	2 51	v F	64
		10·6	4 22	F; p L; R; b M	115
1079	II. 382	11 57 13·1	68 28 1	e F	423
		...	28 ±	No description	409
1080	III. 400	11 57 19·6	52 10 38	e F; v S; like a *; is n f a * 11 m, 2′ dist	72
		22·1	11 27	v F; R; v s b M; has * 10 m, 45° sp, 90″ dist	331
1081	I. 207	11 57 19·7	41 34 33	B; v L; m E, in pos 32°·0; seen through much fog	330
1082	III. 383	11 57 21·6	68 25 31	No description	423
		21·9	26 10	v F; R; b M	244
		...	26 30	No description	409
1083	III. 326	11 57 26·9	63 29 28	e F; R; v g b M	407
		28·9	29 58	v F; R	58
1084	III. 717	11 57 27·6	39 28 46	p B; v L; m E in pos 166·5; 3′ l, 1′ br; v g v l b M. This cannot be either I. 206 nor I. 207, as neither of these agrees in its angles of position.	329
		...	29 37 :	Nearly as B and L as I. 207; and the position is from n p to s f. Both therefore exist. Taken past merid. PD therefore precarious.	330

No.	Synonym.	R 1830·0.	N.P.D. 1830·0.	Description and Remarks.	Sweep.
		h m s	° ′ ″		
1085	I. 225	11 57 43·3	36 20 33	B; R; p s b M; has a * 12 m 35″ s p very near the edge	328
1086	II. 370	11 57 54·3	60 52 26	p B; R; b M	64
		55·8	52 29	p B; 60″; moon and haze	67
		56·3:	51 31:	p B; R; s b M; 40″. Uncertain obs; between clouds	65
		56·8	52 56	v F; l E	66
		57·4	52 52	B; R; g m b M; 30″	417
		59·6	53 22	p B; not v S; E; l b M	115
1087	Nova.	11 58 7·9	21 53 41	B; R; g b M; 20″; first class	412
1088	I. 195	11 58 18·7	45 59 52	v B; v m E, in pos 151°·0; v s v m b M; 40″ l, 10″ br	248
		23·0	58 57	B; S; m E; s b M; a double * points to its nucleus	150
1089	Nova.	11 58 28·5	55 3 45	e F	337
1090	Nova.	11 58 29·6	74 39 12	A suspected neb. Extremely faint	24
1091	III. 708	11 58 55±	46 2 15±	In a straight line prolonged from I. 195 through a double star near it.	248
1092	V. 4	11 59 25·4	86 10 36	v F; not v L; E or bicentral; b M	143
		29·1	10 40	F; v L; E; g b M; 3′ l, 2′ br; has * 16 m in nucl, and 1 or 2 more suspected.	141
1093	Nova.	11 59 27·3	56 3 6	e F; v S; R; m b M	74
1094	I. 33	11 59 29·1	78 40 18	v B; m E; 30° n p to s f; b M	120
		29·2	41 15	p B; p m E; 30° n p to s f; 2′ l	191
		...	40 12::	E in a n p direction towards a *	3
1095	III. 68	11 59 56·2	72 55 10	v F; S; R; p s l b M	419
1096	I. 279	11 59 57·9	12 15 12	e F; R; v g l b M	413
		60·0	15 7	F; R; l E; g b M; 20″	170
1097	II. 548	12 0 10·4	98 5 38	p F; E; g b M; very ill defined	137
		10·8	5 4	F; v g b M; E in parallel; 30″ l, 20″ br	136
1098	III. 356	12 0 15·3:	59 46 11	v F; S; R; the n p of 3 in a line	66
		16·8:	46 1	F; S; R	68
1099	II. 371	12 0 18·8:	59 48 51	F; S; R; the second of 3 in a line	68
		21·5	48 7	F; the n p of 2 (the third not seen)	342
		22·8	49 51	v F; S; the second of 3 in a line	66
1100	I. 278	12 0 28·6:	14 8 57	F; R; g b M. Strong twilight	349
		30·0	9 42	p B; R; g b M	413
1101	III. 357	12 0 28·8	59 52 41	p B; l E	68
		30·3	53 31	F; p L; the third and s f of 3 in a line	66
		30±	50 ±	B; the s f of 2; place by rough estimation	342
1102	III. 795	12 0 58·7	30 11 59	F; p L; l E; g b M; 40″	345
1103	III. 814	12 1 0·1	35 56 5	v F; irreg fig; v g l b M; twilight	347
1104	IV. 54	12 1 12±	46 34 2	R; s b M to nucleus	150
1105	I. 169	12 1 22·9	49 10 36	p B; v L; dilute; v g l b M	73

No.	Synonym.	R 1830·0.	N.P.D.1830·0.	Description and Remarks.	Sweep.
		h m s	° ′ ″		
1106	I. 19	12 1 21·4	70 29 41	B; R; 80″; consists of distinct stars. A globular cluster. P D mistaken 1° in obs; corrected.	61
		24·4	30 47	vB; resolved	63
		24·9	30 21	v B; R; 40″. I see the stars of which it consists	334
1107	II. 747	12 1 21·8	42 36 9	F; v m E in pos 109°·0 by measure; v g b M 4′ long, 30 or 40″ br	255
		23·5	36 27	p B; g b M; a long narrow ray; 3′ l, 30″ broad	140
1108	II. 321	12 1 34·9	59 8 4	v F; v L; 5 or 6′ diam. The minute in R doubtful; perhaps 0^m	67
1109	II. 802	12 1 51·7	30 46 12	No description	323
1110	I. 73	12 1 55·0	58 39 4	B; R; p g m b M; 25″; a * 8 m 5′ p	342
1111	I. 165	12 1 55·2	49 38 41	v s m b M to a * 10 m; the s p of 2, 6′ distant	73
		55·7::	40 18::	v B; S; R; p g b M; 30″	335
1112	II. 83	12 1 56·3	73 1 26	v B; R; p g m b M; 40″	418
		56·9	1 23	No description	422
		57·1	1 31	p B; S; R; g b M; 20″	419
1113	II. 642	12 2 12·7:	49 36 51:	v F; 1E; v g b M	335
		17·3:	34 37::	The n f of 2. Place by estimation from the other, and of course very rough.	73
1114	I. 208	12 2 29·8	38 33 53	B; v m E; v g l b M; 4′ long	328
1115	II. 405	12 2 32·4	68 52 57	v F; has a * n f	59
1116	III. 941	12 2 36·3	12 55 47	e F; R; makes equilateral triangle with 2 stars	413
1117	II. 353	12 3 15·2	64 55 48	B; L; E; b M; 60″	58
1118	Nova.	12 3 33·1	52 33 2	F; p L; R; v g b M; a D * s p dist 10′. The MS obs makes the P D decidedly 33′; but *should* it be a mistake for 52′, this nebula would be identical with III. 399.	331
1119	II. 105	12 3 36·7	75 51 4	B; R; p s b M; irreg fig; r	242
1120	II. 372	12 3 40·8	59 53 1	p B. The first of 4 in a trapezium	65
		45·3	53 31	The first of a trapezium	66
1121	III. 358	12 3 43·3	59 50 ±	The second of a trapezium	65
		48±	50 ±	The second of trapezium. Place estim	66
1122	III. 359	12 3 44·3	59 55 ±	The third of trapezium. Place by estim	65
		50±	56 ±	The third of trapezium; place by estim	66
1123	II. 742	12 3 46·1	32 52 57	p F; S; E; g b M; 15″ l, 12″ br	345
1124	III. 360	12 3 53·3	59 54 ±	The last and largest (by diag) of trapezium	65
		58±	53 ±	The last of trapez. Rough place	66
1125	Nova.	12 4 5·4	78 11 40	v F; v L; E; a * 7 m follows 7′ ± dist	191
		...	12 32	v F; E n f to s p; 40″	3
1126	I. 9	12 4 10·8	87 45 27	p B; S; m E; a ray with a nucleus pos 45° n p to s f	145
1127	II. 133	12 4 19·1	82 1 9	B; R; p s b M; 40″	117
		21·6	0 43	No description	252
		22·4	1 15	p B; E; v g b M; 20″	250
1128	III. 697	12 4 40·4	45 22 47	v F; L; v m E; 2′ l, 30″ br	150
		44·0	22 22	v F; v m E, pos 170°·0 ±; 90″ l, 30″ br	248

No.	Synonym.	Æ 1880·0. h m s	N.P.D. 1880·0. ° ′ ″	Description and Remarks.	Sweep.
1129	II. 373	12 4 42·6	60 32 39	v F; R	67
		43·4	33 7	p F; p L; R; g b M	343
		45·2	33 2	v F; v L; R; g b M; 2½′ diam	417
		49·3::	34 ±	Place coarsely estim from a neb following	68
1130	Nova.	12 5 5·8	81 51 7	No description	251
		7·8	51 13	F; R; near a small *	252
		8·2	51 7	v F; R; b M	253
		8·7	50 41	No description	254
1131	II. 106	12 5 6·9	75 38 10	p B; L; l E; v g l b M; 2′ diam	338
1132	M. 98	12 5 8·0	74 8 12	B; v m E, a ray, pos 70° s f to n p; m b M almost to nucleus; 10′ long; 6 comæ entered, bisected by the same horizontal wire.	24
		8·1	9 0	p B; v s b M to nucl; a long ray pos = 153°·0 by meas; 8′...10′ l, 30 br.	419
		8·4	9 34	B; L; m E pos 152°·1 by meas; v s v m b M 8′...10′ long. A fine object.	422
		...	9 16	B; L; v m E; p s b M; precedes 6 comæ about 30′ of space ..	421
1133	II. 409	12 5 8·3	52 25 27	v F; p L; R; v g l b M; 40″	331
1134	II. 163	12 5 12·8	75 53 4	v F; p L; E; v g b M	242
1135	II. 867	12 5 36·5	34 30 45	F; v s m b M to a * 12 m; 20″	347
1136	II. 374	12 5 52·2	60 37 32	B; v s v m b M to a *	417
		52·8	38 37	p B; S; p s b M	343
		54·0:	37 54	F; S; R; b M	68
		61·0	38 54	B; S; s b M	67
1137	II. 134	12 5 56·5	83 14 53	p B; E; v g b M; 20″; like II. 133	250
1138	II. 164	12 5 58·3	76 53 46	e F; R; b M	19
		63·4	52 38	p B; R; p s l b M; 40″	340
1139	II. 793	12 5 59·8	33 2 17	p F; S; l E; g b M; like II. 792	345
1140	I. 175	12 6 29·3	55 51 26	B; R; s m b M	74
		31·5	51 24	v B; R; p s m b M	131
1141	III. 397	12 6 36·5	68 24 10	e F; L; v g l b M; 45″	409
		...	23 ±	e F	424
1142	II. 107	12 6 47·7	75 9 24	v F; p L; R; g b M	243
1143	III. 850	12 6 55·0	23 4 28	Not v F; p L; R; v g b M; 30″	412
1144	II. 108	12 6 57·4::	75 8 40	B; L; E; v g b M; 90″ l, 75″ br	419
		61·9	9 20	B; L; l E in parallel; at first gradually and then s b M; r; 3′ diam	338
1145	II. 354	12 7 0·2	65 3 58	v F; v S; R	407
1146	I. 95	12 7 5·1	52 44 2	B; L; g b M; 50″; has a double nucl very indistinct. The diagram makes it a double neb, the two running ogether. See fig 71.	331
1147	II. 135	12 7 11·3	82 39 6	B; p L; irreg fig; g b M	117
		12·8	39 7	p B; E; p g b M; 25″ l, 20″ br	253
		14·3	39 12	v B; m E; v s b M to a * 11 m	250

No.	Synonym.	Æ 1830·0. h m s	N.P.D. 1830·0. ° ′ ″	Description and Remarks.	Sweep.
1148	I. 109	12 7 14·7	75 54 4	B; E; r	192
		15·4	54 29	v B; v L; a nucleus with two branches extended in pos 75° n f to s p. (See fig 59.)	242
		...	55 ±	A very remarkable long ray extended 70° n f to s p, 7½′ long, s m b M. It has a * n f the nucleus. Rough place.	3
		...	53 30:	B; m E; p s b M. (N.B. No neb at 76° 2′. Seen also in Sw 2, but the place and description too rough to be of use.)	340
1149	II. 748	12 7 17·1	41 57 16	F; m E; s of 2 bright stars	329
		18·8	59 34	p B; v m E in pos = 225°·0 by meas; 5′ l, 1′ br; 2 st near and , a L * p.	255
		19·5	58 34	F; m E; 2′ l; has 2 st, 9 and 11 m, n f	138
		19·9	60 ±	F; L; E; has a * 1ᵐ·0 following and another near	139
		...	59 6:	g b M; E; 70° n f to s p; is s of a coarse double *	140
1150	Nova.	12 7 41·2	22 49 23	p B; S; R; p s b M; 15″	412
1151	I. 209	12 7 42·7	41 10 33:	p B; p m E in pos = 314°·4; p s b M. (Foggy.)	330
1152	II. 137	12 7 45·5:	82 21 31	p B; R; Æ estimated from III. 480, which it precedes on same parallel.	254
1153	II. 136	12 7 46·4	81 35 44	p B; p L; l E; g b M	251
		53·3	35 33	p B; R. Hazy, clouding over	252
1154	Nova.	12 7 52·6	101 21 49	F; e S; R; 5″; has a * 8 m, 80° s f, dist 60″	129
1155	Nova.	12 7 58·7	42 2 32	F; S; l E; the second of 2 in field	139
1156	II. 518	12 7 59·8	55 32 36	p B; R; b M	74
		61·3	31 37	p F; R; p s b M; the s p of 2	131
1157	Nova.	12 8 1·5	52 43 41	v F; L; R; g b M; 90″	72
1158	II. 519	12 8 4·8	55 30 1	The n f of 2	74
		7·3	29 14	F; R; p s b M; 65° n f the neb II. 518	131
1159	II. 17	12 8 24·2	81 51 24	p B; l E; g b M	251
		29·1	51 57	v B; p m E; v s b M; among small st	253
1160	Nova.	12 8 27·5	85 22 30	p B; L; R; g b M; 60″	141
1161	II. 496	12 8 27·8	81 25 59	p B; R; v s b M to a S nucleus; 20″	254
1162	II. 11	12 8 31·5	73 45 2	e F; but haze and strong twilight	27
		33·0	43 44	B; L; l E; v g b M	422
1163	V. 17	12 8 37·3	19 38 0	Immensely L; v F; m E; v g b M; it fills more than a field, but is hardly distinguishable. Hazy.	377
1164	III. 851	12 8 37·5	25 38 56	v F; not v S; R; v g l b M; 15″....20″	411
1165	III. 480	12 8 45·5	82 23 11	v F	254
		45·7	22 30	v F; v g b M; a * 7 m to south	250
1166	III. 725:	12 8 48·9	43 26 9	F; v L; R; v g b M; diam in Æ = 15ᵐ·0 of time. Sky quite clear. (illuminating wires.	256
		51·9	25 29	F; L; R; v g b M; r; has * 10 m, 2′ f	140
1167	V. 41	12 8 56·7	51 15 12	F; v m E; a v long narrow ray pos = 43°·2 by meas, at least 9 or 10′ l, extends across the field.	331
		57·8	14 5	p B; v m E; a long ray, 50° n f to s p ± by estim; 12′ l, 90″ br	73

Fig. 59.

No.	Synonym.	R 1830·0. h m s	N.P.D. 1830·0. ° ′ ″	Description and Remarks.	Sweep.
1168	I. 74	12 8 59·6	59 26 56	B; pL; r	66
		62·1	26 41	vB; R; sbM; 60″	65
		62·9	27 5	vB; pL; R; psbM	342
1169	II. 742	12 9 17·8	41 38 46	eF; hazy	329
		20·0	39 29	vF; pmE; psbM	255
1170	I. 264.	12 9 31·3	18 15 17	pF; S; R; pgbM; 15″	377
1171	I. 89	12 9 31·7	60 52 52	vB; vsvmbM; has * 6.7 m 1½ min (of time) following	417
		33·2	52 57	vB; S; mE; vsmbM; nucleus elliptic	343
		...	52 18:	vB; R; bM	68
1172	III. 702	12 10 0±	59 13 ±	vF; R; 20″	342
1173	M. 99	12 10 9·9	74 38 36	Not vB; R; vgbM; 5′ diam	421
		10·0	38 34	pB; vL; R; gbM; r; 5′ diam	422
		10·8:	36 55:	B; R; gbM; r; 5′ diam.	419
		...	38 24	B; L; R; gbM. Seen through cloud	418
1174	II. 846	12 10 29·1	23 9 23	pB; vmE in pos = 218°·2; 90′ l	412
1175	V. 43	12 10 30·8	41 45 18:	vB; vL; vsvmbM to an oval nucl; 8 or 9′ long, 4 or 5′ broad. (See fig 55.)	330
		32·7	46 19:	vB; vL; vsbM to an oval nucleus which is not in the middle of its length; 6′ l, 3′ br.	255
		32·7	44 6::	vB; vL; sbM to a *; 6′ l, 4′ br	329
		...	46 56::	vB; L; vmE	256
1176	II. 139	12 10 32·7	83 13 51	vB; pL; R; psmbM; 40″	250
1177	II. 138	12 10 40·7	82 57 33	pB; through thick haze	252
		41·3	57 10	B; E; psbM	253
1178	Nova.	12 10 41·1	83 43 ±	Precedes four more, nearly in parallel	117
1179	II. 110	12 10 50·6	74 10 51	B; S; R; like a * 11 m with a burr	421
1180	II. 140	12 10 54·4	83 12 30	pF; R; gbM; 30″	250
1181	II. 166	12 11 5·2	76 16 15	pB; R; sbM	191
		7·7	15 44	pB; R; vsmbM, almost to a *	243
1182	III. 299	12 11 14·3	58 42 49	eF; vS; R; 10″	342
1183	Nova.	12 11 16·3	83 43 34	B; L; E; gbM.	238
1184	II. 376	12 11 18·2	61 26 17	F; R; gbM; 20″	343
		...	25 42	F; lE; near a * 15 m	417
1185	I. 75	12 11 16·6	59 26 15	vB; vL; E in parallel; 2′ l, 1½′ br	65
1186	I. 90	12 11 32·6	59 46 21	vB; R; smbM; r	66
		32·7	46 29	vB; pL; R; gmbM; 90″	67
1187	II. 573	12 11 40·6	83 40 34	vB; vL; R; pgbM; 3′; 3 more seen	238
1188	II. 377	12 11 47·7	59 44 29	B; R; S; bM; 30″	67
		48·1	44 11	B; R; sbM	66
1189	Nova.	12 11 53±	83 44 ±	vF; S.	117
1190	Nova.	12 12 3·1	83 42 34	vB; R; the central neb of 4 in a trefoil	117

Fig. 55.

No.	Synonym.	$\mathcal{R}$ 1830·0.	N.P.D. 1830·0.	Description and Remarks.	Sweep.
		h m s	° ′ ″		
1191	III. 726	12 12 10·0	42 45 34	pF; R; v g b M; 60″	138
		11·3	45 56	v F; L; v g b M; irreg R; r	140
		13·4	47 22	e F; p L; R	139
1192	I. 275	12 12 14·5::	13 41 2	p F; S; E. The reductions of the $\mathcal{R}$ in this sweep are precarious.	348
		40·0	40 43	F; S; s b M; 10″; a * 15 or 16 m precedes	170
		41·0	41 32	p B; stellar; v s m b M. The first of a trapezium of stars	413
		48·6	41 12	p F; R; g b M; 20″; followed and almost surrounded by 3 stars 10 m, one of which is double; has also a v S * s p dist 30″.	349
1193	II. 805	12 12 20·2	30 57 37	p B; L; R; g b M; 60″	345
1194	Nova.	12 12 28·6	83 40 34	v B; E; b M; 60″	117
		28·8	39 19	p F; R	251
1195	V. 5	12 12 32·2	70 39 36	F; v L; E; b M; 5′ l, 1½′ br	61
		33·5	40 57	L; E; l b M	63
1196	Nova.	12 12 34·2	84 27 32	F; R; v g l b M; has a * 70° n p; 1′ dist. Taken for I. 139, but this neb does not exist, or is identical with M 61.	143
		...	28 35	F; S near a B *; precedes M. 61 about half a field	141
1197	II. 61	12 12 33·8	77 33 19	p B; p L; E n p to s f; has another f in same parallel	19
		34·2	33 11	F; L; b M; E 45° n p to s f; 2′ l, 1′ br	22
		39·2	32 59	F; v m E; like a double neb composed of 2 R nebulæ	242
		39·9	32 17	F; m E; L; v g b M; 3′ long	338
1198	II. 111	12 12 53·2	74 27 16	F; L; E; v g b M; a star follows; the p of 2	421
		53·9	26 29	The p of 2; by diagram E in merid, nearly parallel to the other	422
1199	II. 112	12 13 0·2	74 27 16	L; v m E nearly in merid; the f of 2	421
		3·4	26 29	The f of 2; both m E and nearly parallel	422
1200	II. 62	12 13 0·7	77 33 0	F; p L; E. (Seen also in Sw 19.)	242
		1·5	33 2	v F; L; l E; v g b M; 3′	338
1201	II. 572	12 13 1·2	83 40 23	F; l E; v g b M	250
1202	M. 61 =I.139	12 13 12·8	84 34 55	B; v L; v s b M to a * 11 m, with a v F atmosphere about it. This nebula is probably identical with I. 139. (See fig 69.)	141
		13·7	34 56	B nucleus in a v F atmosph 2′ diam, gradually fading away	142
		...	.....	Viewed; v faintly bicentral. The two nuclei 90″ dist pos 45 ... 50° n f.	143
1203	Nova.	12 13 25·2	76 19 35	v F; R	191
1204	I. 76	12 13 53·0	59 9 46	v B; E; s b M; points to * 60° n p	65
1205	II. 378	12 13 54±	59 50 ±	v B. The n p of 2	68
		...	50 34	Past merid. No $\mathcal{R}$ procured	67
1206	Nova.	12 13 54·0	59 51 8	F; the s f of two	68
1207	II. 63	12 13 58·0	77 17 12::	e F; E 45° n p; r in middle	3
		59·4	15 39	v F; L; R; 60″	243
1208	Nova.	12 14 5·7:	80 51 20	e F; a * 8 m 5′ dist, on merid, to n	120
1209	II. 628	12 14 9±	73 30 57	p B; p L; E; g b M; $\mathcal{R}$ by working list	419

Fig. 69.

No.	Synonym.	$\mathcal{R}$ 1830·0.	N.P.D. 1830·0.	Description and Remarks.	Sweep.
		h m s	° ′ ″		
1210	I. 276	12 14 10·5	13 43 48	p B; S; s b M; 15″	170
		16·9	44 27	p B; p L; b M. Follows I. 275	413
		19·7	43 42	F; R; b M; 18″; the f of two in field	349
1211	M. 100	12 14 17·9	73 14 34	p B; R; p s m b M. Not a very remarkable nebula. II. 84 was not seen.	422
		19·3	13 39	Barely visible through cloud	418
		20·8	13 26	v L; s m b M; a nucleus with dilute borders	25
		...	13 56	v F; v L; R; v s b M to a p B nucleus	421
1212	II. 85	12 14 30·0	72 20 5	p B; R; p s b M	419
1213	II. 141	12 14 30·2	82 58 51	v F; S; R; b M; 10″; the first of 3 in a triangle	254
1214	Nova.	12 14 35·8	101 35 29	F; v S; R; b M to nucleus	129
1215	II. 142	12 14 40·7	83 1 1	F; p S; R; b M; 15″; the second of 3 in a triangle	254
1216	II. 847	12 14 41·3	23 12 43	F; R; v g b M; 20″	412
1217	II. 806	12 14 41·6	30 36 52	p F; S; b M	323
		41·9	37 12	p B; S; E; g b M; good obs of place	345
1218	Nova.	12 14 44·3	81 35 7	p F; R; S; close to a *	253
1219	II. 406	12 14 47·2	69 38 22	v F	63
		52·8	37 56	F; p L; R; b M	61
1220	III. 942	12 14 52·1	12 53 7	e F; hardly discernible	413
1221	II. 86	12 14 52·5	72 21 5	v B; m E; v s b M; 35″ long	419
1222	II. 143	12 14 54·2	82 58 31	B; R; p L; p s b M; 30″; the third in a triangle	254
		54·8	57 44	B; R; g b M; neat and bright, but only one seen. (This must therefore be the brightest.)	251
		55·3	58 14	p B; R; has a * 10 m 1′ s	117
1223	III. 94	12 14 58·3	82 6 59	p B; E, or has a F neb on the s f side	250
1224	III. 31	12 15 1·6	71 31 1	F; not v S; R; v g l b M; 25″	334
1225	I. 210	12 15 4·5	42 3 23:	p B; S; p m E; p s b M; 40″	330
		5·8	5 34	B; S; E; v s b M; 50″ l, 20″ br	255
		6·5	3 59	v B; S; m E; v s m b M	138
		6·5	4 13	v B; a * with a short sharp ray; by diag pos 10° s f to n p. (See fig 57.)	140
		6·6	3 52	v B; S; m E in parallel; v s m b M to nucleus	139
		...	3 46:	B; S; R; p s b M; hazy	329
1226	II. 625	12 15 4·6::	92 30 4	F; irreg R; a small * p. ($\mathcal{R}$ reductions in this sweep considerably uncertain.)	21
		10·8	30 32	F; p L; E; v l b M. ($\mathcal{R}$ to be preferred.)	146
1227	II. 64	12 15 25·4	77 50 13	v F; S; l E; (nisi $\mathcal{R} = 12^h\ 16^m\ 25^s{\cdot}4$)	338
		...	49 30	No description or observed $\mathcal{R}$	340
1228	I. 123	12 15 37·5	84 7 32	B; visible in strong twilight; has a * 8.9 m 20° s f dist 3′; (nisi $\mathcal{R} = 12^h\ 16^m\ 25^s{\cdot}4$)	153
1229	III. 648	12 15 40·1	57 32 25	F; p m E, nearly in parallel; v l b M; 25″	342
1230	III. 799	12 15 42·1	30 40 32	F; l E; the p of 2	345
1231	I. 65	12 15 43·4	107 50 4	v B; L; R; v s m b M to nucl = *11 m 90″ diam. r with power 320, and is no doubt a globular cluster; fades away to nothing.	149

No.	Synonym.	R 1830·0.	N.P.D. 1830·0.	Description and Remarks.	Sweep.
		h m s	° ′ ″		
1232	I. 30	12 15 49·0	81 44 14	v B; R; at first g b, then s m b M; 50″	251
		50·1	44 33	Just visible through cloud	252
		...	44 7	No description	253
1233	III. 800	12 15 50·1	30 41 32	e F; the last of 2. (The other was III. 799; III. 801 not seen.)	345
1234	I. 166	12 16 10·3	49 40 39	p B; R; s m b M almost to a *	73
		11·5:	41 31::	v B; R; p g m b M; 30″; r	335
1235	I. 22	12 16 14±	77 21 32:	g b M; 20″. Rough place	3
		14·0	21 9	B; R; g b M; 30″	22
		15·3	22 5	B; R	191
		...	19 ±	v F; R; v g b M; 20″; very rough place	2
1236	II. 144	12 16 14·2	81 36 29	p F; R; b M; 40″	117
		14·9	37 17	p B; S; E	253
1237	M. 84	12 16 26·2	76 10 9	v B; R; p s b M; 60″; r	192
1238	II. 379	12 16 29·0	60 30 13	F; R; has a S * 35° n f, 90″ dist.	66
		29·5	29 55	F; R; b M	68
1239	I. 12	12 16 36·1	74 17 44	B; S; v s m b M	422
1240	Nova.	12 16 41·8	73 25 31	p L; R; s m b M to nucleus	25
1241	Nova.	12 16 45·5	79 3 1	v F; p L; R; l b M	19
1242	M. 85	12 16 47·6	70 51 56	v B; R; b M; 2′ diam; has a * 80° n p dist 30″ from edge	61
		49·5	52 26	v B; v s b M; 60″	334
1243	III. 879	12 16 54·1	84 32 50	e F; hardly sure that I see it. Sky very dull	346
		56·0	33 15	p B; S; R; g b M; 12...15″	347
1244	Nova.	12 17 9·8	76 24 34	v F; E; the p of 2, dist about 30ˢ in R A	192
1245	II. 749	12 17 11·5	43 22 29	F; v L; E; v g l b M; 2′ l, 1½′ br	255
		11·9	22 1	p B; p L; irreg R; g b M	140
		14·8	22 22	p F; p L; m E	139
1246	III. 361	12 17 18·2:	61 29 50	F; irreg fig; has a line of B st preceding	68
1247	I. 277	12 17 18·4	13 32 17	p B; l E; p s m b M; 25″	348
		18·4	31 52	B; l E; p s m b M	349
1248	III. 852	12 17 18·9	24 7 18	v F; S; R; s b M. Has a triple * s p	412
		20·6	7 11	p B; S; b M; 12″. Near a p B triple *	411
1249	III. 729	12 17 19·9	43 15 21	F; S; R; v g b M. R A from II. 749, which it follows 10ˢ	140
1250	II. 167 / II. 168	12 17 20±	76 19 2	These and several more seen	3
1251	II. 55	12 17 20·6	70 50 41	p B; l E; b M. In field with M. 85	61
		21·5	51 6	p B; l E. Follows M. 85	334
1252	V. 29. 1	12 17 22·2	55 30 36	Two nebulæ running into one another; both e F; v L; the f rather the brighter. Place that of the preceding. (See fig 68.)	74
	V. 29. 2	12 17 29·7	55 32 36	The following nebula of V. 29	74
		33·0	32 22	v L; extremely ill defined, may perhaps be 10′ l, 3′ br; p s l b M to an irregular centre. On closer examination bicentral; pos of the nuclei 30° n p; dist 2′.	131

Fig. 68.

No.	Synonym.	Æ 1830·0. h m s	N.P.D. 1830·0. ° ′ ″	Description and Remarks.	Sweep.
1253	Nova.	12 17 28·9	76 7 6	v B; R; g b M to nearly a star	22
		35·0::	7 14	v B; L; p g m b M; r. (Æ precarious.)	243
1254	II. 88	12 17 32·3	72 53 11	p B; R; v s b M; 30″	421
1255	Nova.	12 17 39·8::	76 25 ±	The following of 2	192
1256	Nova.	12 17 43·0	80 2 45	e F; v L; R; g b M; 2½′ diam	120
1257	II. 34	12 17 53·9	85 6 0	F; p L; g b M	141
		54·8	5 49	F; L; R; v g b M	238
1258	I. 77	12 17 59·5	57 50 3	v B; L; p m E, first g b and then v s v m b M to a nucleus = * 11 m; 3′ l, 90″ br.	342
		...	50 38	B; L; l E; s m b M; 4′ l, 3′ br.	74
1259	II. 169	12 18 1·1::	76 29 32	e F; g b M; has 2 st, n and n p	3
1260	Nova.	12 18 5·6	81 8 24	v F; L; R; 60″; has * 7 m, 5′ s p	117
1261	III. 492	12 18 12·4	89 56 37	F; S; R; near a *	146
		...	56 42	F; R; b M	145
1262	II. 113	12 18 18·2	74 0 52	B; E, n p to s f; s b M	24
1263	II. 23	12 18 18·3	86 33 33	v F; l E; 30″. This may possibly be identical with III. 17.	143
		19·2	33 56	p B; r	142
1264	II. 89	12 18 26·5	73 35 46	p B; R; p g b M	422
		30·8	34 36	A star n p	25
1265	III. 492	12 18 26·9	94 53 1	v F; S; R; p s b M	147
		27·5	53 21	Not v F; R	234
1266	II. 145	12 18 29·9	83 10 43	v F; v S; E	250
1267	II. 170	12 18 31·2:	76 20 22	p B; S; R; b M	19
		36·1	19 59	No description	242
1268	II. 171	12 18 36·9:	76 45 45	v F; oval; g b M; 50″	340
1269	Nova.	12 18 43·4	97 14 15	p L; v F; very ill defined	137
1270	II. 146	12 18 46·3	82 48 37	v F; L; R; g b M; 90″	253
		49·1	47 24	v F; v L; R; v g b M; 50″	251
1271	Nova, or II. 65	12 18 48·3	77 57 15	B; L; p m E; p s b M; has * 10 m n f, 1′ distance	191
		50·3	58 26	v B; L; E; has * n f; 2′ dist, pos = 29°·4 by micrometer	245
1272	II. 172	12 18 50·9:	76 43 55	v F; g b M; 40″	340
1273	Nova.	12 18 53·4	97 20 50	Not v F; p L; l E; very ill defined	137
1274	M. 86	12 18 57·9::	75 60 1	The preceding of 2	22
		62·4	58 19	No description	338
		62·6	59 24	v B; R; 30″	242
1275	I. 28	12 19 2·9:	76 3 46	B; R. The f of 2	22
		6·1	3 34	p B; L; l E; 60″	242
		7·4	2 34	p B; v L; the f of 2	338
1276	II. 173	12 19 3·9	76 45 50	B; R; b M; 50″; r	340
1277	Nova.	12 19 7·2	88 55 42	F; v m E, pos 15° n f to s p; a long ray; it is s p a * 10 m. The place is that of the star.	145

No.	Synonym.	N.P.D. 1830·0.	AR 1830·0.	Description and Remarks.	Sweep.
		h m s	″ ′ °		
1278	II. 848	12 19 24·1	24 15 21	pF; R; vgbM; 25″	411
1279	II. 156	12 19 26·6	79 14 55	vB; R; smbM; 30″	120
1280	I. 91	12 19 43·8	60 26 41	B; L; 1E	65
		45·4	26 42	pB	417
		45·7	26 42	B; L; mE exactly in parallel; smbM	343
		...	26 11	No description	415
1281	I. 213	12 19 47·2	44 58 42	B; L; gbM; E in pos 75° nf to sp a fine cluster; well resolved; I see several of the stars; 3′ l, 2′ br.	150
		49·4	58 8	vB; resolved; has as it were a forked tail	151
		49·6	57 52	vF; vL; vmE; it is either a double neb, or the n f end is bifid. If double the companion is F; R; bM; nearly north dist 1½′ or 2′. A fine object.	248
		50·6	57 57	vB; vL; mE. The centre is fairly resolved; 3′ l, 2′ br. Borders hazy.	139
1282	II. 56= II. 90	12 19 53·2	71 58 44	B; pL; R; psbM; 2′	422
		53·7	59 2	pL; R; bM nearly to nucleus	27
		53·9	58 55	vB; L; R; psbM; 60″	419
		54·4	58 2	vB; 1E; pgbM; 100″. (N.B. II. 90 and II. 56 appear to be identical.) Carefully examined. No other found near the place.	334
		54·5	58 6	B; L; R; gvmbM to a stellar nucleus	25
		54·6	58 57	pB; pL; R; bM	63
		...	58 19	F; pL; has a * 9 m sp; 5′ dist	418
		...	57 38 ::	pB; L; bM; 60″; r	61
1283	II. 26	12 20 7·3	82 32 51	eF	254
1284	II. 180	12 20 7·9	91 0 12	F; R; gbM; 20″; a stellar point 18 m in the centre; 2 B st precede, distant.	146
1285	II. 355	12 20 11·0	66 14 30	pB; pmE; gbM; two B stars nf	424
		11·4	14 25	vF; pL; 1E	409
1286	II. 35	12 20 18·1	85 29 19	B; R; vsbM; 20″	288
		18·2	29 3	B; R; psbM; 30″	143
		18·5	29 14	vB; S; R; smbM to nucl = * 10 m	142
1287	II. 121	12 20 20·4	75 49 8	pB; R; psbM; the p of 2	338
1288	I. 161	12 20 22·1	75 4 20	pB; R; bM; r; has * 8 m 2′ dist, 45° sf.	23
		24·0	5 34	F; R; bM; 30″	243
1289	I. 212= II. 750	12 20 24·7	44 10 31	pB; pL; E; psbM. (I. 212 and II. 750 seem to be identical.)	255
		...	13 ±	B; mE; rough place	140
1290	II. 122	12 20 25·9	75 52 23	pB; R; psbM; the f of 2	338
		...	51 3:	vF; R; vgbM; 15″	2
1291	II. 848?	12 20 41·0	24 15 43	pB; R; gbM. (N.B. My Father's P D; if this *be* the nebula, II. 848 is nearly 6′ in error.)	412
1292	III. 483	12 20 43·9	80 54 5	pB; vS; pgbM; R; 10″	250

No.	Synonym.	AR 1830·0.	N.P.D. 1830·0.	Description and Remarks.	Sweep.
		h m s	° ′ ″		
1293	II. 18= II. 498	12 20 58·1	81 14 14	B; L; irreg R; b M; r	117
		59·6	13 59	v F; R; b M	251
1294	M. 49	12 21 7·0	81 3 32	R; p g m b M; 40″. Through cloud; twilight	153
		7·3	3 33	Seen in strong twilight; a very good obs of place; has a * 13 m 0° f; 60″.	154
		8·1	4 6	v B; R; v s b M; 2′ diam; a * 4·0 f	250
		8·7	3 57	e B; L; R; p s m b M; insensibly fading away, has a * 13 m f; by diag the star is just beyond the nebula.	253
		10·1::	3 43	B; L. Cloudy	252
1295	II. 629	12 21 17·1	74 59 22	p B; R; b M; 20″	24
1296	II. 123	12 21 17·8	76 44 23	The first of 3	19
		23·4	43 46	F; R; S; b M	245
		...	.....	v F; R; place estimated, but too roughly to be of any use	191
1297	III. 362	12 21 18·8	61 48 37	e F; R; 15″	417
		...	48 22	e F; no R A procured	343
1298	II. 124	12 21 36·6::	76 45 23	No description; R A precarious	19
		39·3	45 35	p B; R	191
		41·7	43 34	No description. (Obs probably hurried.)	192
		42·0	45 6	B; S; R; p s b M; 30″; the f of 2	245
		49±	43 59	R A roughly estimated from M 87, mistaken for II. 123	22
1299	III. 531	12 21 45·9	84 48 45	F; S; E	141
1300	Nova.	12 22 4·1	100 41 54	Not v F; R; g b M; 20″	129
1301	M. 87	12 22 8·7	76 40 9	v B; R; 60″. (Mistaken for II. 124.)	22
		12·3	41 35	v B; v L; R	191
		12·7	40 4	p B; L; R	192
		17·7	40 58	v B; v L; R; p s m b M; r; 3′ diam	245
		...	41 34::	v B; R; b M. (Taken past merid; P D too great.)	19
1302	III. 484	12 22 13·1	80 41 40	v F; v S; l E	120
1303	II. 91	12 22 17·0	72 18 15	F; R; g b M	419
		17·1	17 36	B; S; R; 25″	421
		17·8	18 1	F. In other respects like II. 56	25
1304	III. 41	12 22 18·8	77 35 5	p B; L; R; 40″	247
1305	III. 499	12 22 21·7	80 59 16	p B; p L; v g l b M; near two small stars	254
1306	I. 197	12 22 49·7	47 26 40	S; R; is 70° n p and 3′ n of I. 198	150
1307	I. 83	12 22 54·4	63 16 58	v B; R; v s m b M to a nucl; 40…50″	58
1308	I. 198	12 22 55·5	47 29 28	v B; v L; m E; 40° n p to s f; easily r	150
1309	II. 36	12 22 55·9	85 7 23	No description	143
		57·7	7 35	A double neb; v F; p L; both R; pos 45° s f by diag; the two are in contact; unequal.	141
		60·5	8 31::	Not v F; v L; R; v g b M.	142

No.	Synonym.	R 1830·0.	N.P.D. 1830·0.	Description and Remarks.	Sweep.
		h m s	° ′ ″		
1310	III. 301	12 22 56·8	59 55 1	F; R; 30″	65
		...	55 20	pF; R; psl b M	417
1311	I. 234	12 23 16·7	31 6 17	pB; E; pgb M; a * 9 m f 30″ dist in parallel	323
1312	M. 88	12 23 23·4	74 38 19	B; vL; vm E; 8′ l, 1′ br. The northern half is brighter than the southern.	422
		23·5	38 17	B; L; E; b M to nucl; pos (by diag) = 140°·0 ±; has a * just at its s f extremity.	24
		24·0	38 50	vB; vL; E; gb M. Seen through cloud	23
		...	.....	Viewed; m E in pos = 143°·4 by microm; p s m b M; 7′ l, 1′ br	419
		...	37 9 ::	A mere glimpse through a cloud	418
		...	38 ±	pos = 145°·3 by microm; 8′ l, 1′ br; s v m b M; has a double star s f.	421
1313	II. 66	12 23 26·0::	77 53 32	R; gb M; 30″	3
		28·7	53 4	pB; R; gb M; 30″	242
1314	II. 92	12 23 28·6	72 22 26	eF	421
1315	III. 18	12 23 35±	85 4 56	eF; the following of 2 in the field	142
1316	II. 631	12 23 35·8	75 38 26	vF; p m E in parallel; gb M; a * 9 m, 8′ f	340
1317	Nova.	12 23 38·2	83 14 4	vS; R; a * 13 m with a burr	251
1318	Nova.	12 23 45·4	56 58 2	vF; S; R; lb M	131
1319	III. 834	12 24 8·9	32 35 57	Not eF; S; R; vgb M; 12″	345
1320	III. 302	12 24 17·5	59 20 22	vF; R; b M; 15″	342
		23·9	21 29	eF	68
1321	Nova.	12 24 23·1	25 19 53	pB; R; psb M; 20″	412
1322	Nova.	12 24 31·6	81 12 34	F; S; R; b M; 20″	117
1323	III. 78	12 24 32·2	74 28 45	F; R; vgb M; 40″	419
1324	II. 93	12 24 33·3	72 46 26	F; an extremely dilute nebulosity, with a centre almost stellar.	25
1325	Nova.	12 25 1·6	79 52 50	eF; pL; lE; vlb M	120
1326	Nova.	12 25 4·7	25 27 21	pB; p m E; pgb M; 20″ l, 12″ br; a * 9 m near	411
1327	Nova.	12 25 4·9	101 4 29	vF; irreg R; b M	129
1328	II. 325	12 25 24±	58 48 ±	pF; L; R; 60″. (R A by working list.)	342
1329	I. 38	12 25 24·4	81 22 2	vB; m E; psm b M; r; a L * follows	253
		24·9	21 54	vB; m E; psm b M; a * 8 or 9 m p	251
		25·3	22 3	B. Follows a * 9 m. Good obs of place in a glimpse among clouds.	252
1330	II. 37	12 25 27·7	86 24 28	pB; pL; gm b M; E in pos 30° n f to s p.	143
		29·4	24 30	F; L; E; s b M; ℭ	238
1331	II. 67	12 25 26±	77 45 32	R; s m b M; stellar 10 ... 12″; has 2 st n p and one s f	3
		29·6	44 39	F; S; R; psb M	243
		30·9	44 4	F; vS; has a * 9 m about 30″ foll	192
		32·4	45 26	pB; R; pgb M; 20″	245

No.	Synonym.	R 1830·0.	N.P.D. 1830·0.	Description and Remarks.	Sweep.
		h m s	° ′ ″		
1332	Nova.	12 25 38·9	47 42 38	8 Canum. Not the least doubt of a considerable nebulous atmosphere round this star.	151
		39·2	43 31	8 Canum. Certainly misty though the twilight is strong.....	155
		40·1	42 37	8 Canum. Involved in a considerable nebula 3′ in diam, exactly R; v g b M.	150
		41·5	41 41	8 Canum. Nebulous. (See the remarks on this phænomenon in the Appendix.)	335
1333	II. 157	12 25 39·4	75 59 21	p F; p L; R; v g b M; 80″	339
		39·8	59 24	v F; p L; R; 50″	242
1334	II. 147	12 25 40·2	82 36 16	Not v F; E; v g b M; r	254
1335	II. 94	12 25 43·5	73 30 32	F; R; b M; r	27
		44·9	30 24	p F	422
1336	II. 410	12 25 44·5	53 31 33	e F; E; hardly visible for haze	72
		44·6	32 52	v F; L; R; v g l b M; 45″	331
1337	V. 2	12 25 47·7	86 52 50	p B; v L; m E in pos 20° n p; s b M	141
1338	Nova.	12 26 2·3	70 51 26	p B; p m E.....	334
1339	I. 160	12 26 40·3::	92 51 9	B; E 25° n f to s p; v s m b M to nucl; 60″	21
		42·9	51 21	v B; m E; v s m b M to a r nucleus, 2′ l, 90″ br.....	147
		46·4	51 13	v B; m E, in pos 5° s p to n f; s m b M to a nucleus	146
		51·9::	51 0	B; E, in pos 30° s p to n f; v s m b M to nucl 60″	20
1340	Nova.	12 26 40·6	82 56 41	p F; R; b M; 40″.....	117
1341	Nova.	12 26 41·0	38 15 23	e F; p L; R; 30″	328
1342	III. 493	12 26 43±	89 18 7::	v F; R; g b M; 20″	145
1343	I. 36	12 26 50·5	76 50 17	B; R	22
		55·8	51 41	p B; R; b M; 20″; the s p of 2; pos of the other from this by microm = 33°·5.	245
		...	50 32	The first of 2 nebulæ 3′ asunder; v F	3
1344	III. 802	12 26 50·6	30 9 7	p F; p L; E; v g b M; precedes a * 9 m.....	345
		53·9	9 42	e F; a * follows 2′ dist	323
1345	II. 120	12 26 51·8	74 33 45	B; L; p m E; g b M.....	419
		51·9	34 2	p B; R; b M; 60″.....	24
		52·0	33 40	B; R; p s l b M; 60″	422
1346	II. 850	12 26 52·2	25 32 6	v F; L; wedge shaped, or has a v F * n f, which gives it a distorted appearance.	411
1347	III. 807	12 26 59·1::	30 7 37::	By long and careful attention I think I see III. 807. Place estimated from III. 802.	345
		61·1	7 57	e F; p L; sky not perfectly clear	344
1348	M. 89	12 26 59·8::	76 31 25	B; S; R; m b M; 30″. (R A precarious by reason of a fluctuating zero.)	19
		64·2	30 24	B; R; g b M; 40…50″. (This R A to be preferred to the rest, which are very uncertain.)	192
		...	29 3::	F; R; g b M; 25″; has a * n f; rough P D.....	2
		...	31 32::	R; m b M; rough P D	3

No.	Synonym.	R 1830·0. h m s	N.P.D. 1830·0. ° ′ ″	Description and Remarks.	Sweep.
1349	I. 37	12 27 0·5	76 48 12	F; R; 10ˢ of time following I. 36	22
		2·1:	49 11:	p B; R; b M; 25″. The n f of 2; place by comparison with the preceding.	245
1350	II. 343	12 27 14·4	62 32 17	B; R; s m b M; 30″	417
		15·2	32 27	B; irreg R; v s m b M to a ✱ 12 m	343
1351	II. 380	12 27 20·9	62 9 10	F	68
		...	8 32	No description	65
1352	I. 92	12 27 28·0	61 6 6	v B; v L; m E; 4′ l, 1′ br; 2 or 3 stars near it	64
		31·1	6 6	v B; v L; m E; pos 60° n p to s f; 3 st follow	65
Fig. 83		31·5	6 21	v L; g b M, but not to a nucleus; m E; has 3 stars s f. By a diagram, the southern end is broader than the northern, giving it a clubbed appearance. (See fig 83.)	66
1353	I. 119	12 27 29±	81 23 25	B; L; R; g b M	154
1354	Nova.	12 27 30·9	62 6 10	v F; the n f of 2, (the p is II. 380.); a third suspected	68
1355	III. 407	12 27 34·7	69 44 1	No description	61
		36·4	44 47	p B; p L; R; b M; r	63
1356	II. 68	12 27 50·4	77 37 7	B; S; l E; p s m b M	338
		50·8	37 44	No description	242
Fig. 37. 1357	V. 24	12 27 51·7	63 4 30	v L; an immensely long ray; pos = 134°·6 by microm. (See fig 37.) Both Lord Adare and Mr. Hamilton, who viewed it with me, agreed that a feeble parallel band extends below the nucleus, as represented in a drawing made at the time, from which that of the engraved figure is (principally) taken. Has a ✱ 10.11 m 45° n f, Δ R A = 5ˢ·0. (See fig 37.)	407
		52·9	4 35	v L; 15′ long, pos = 136°·4 by microm; pos of a ✱ 12 m from nucl = 43°·8. The nucleus = a ✱ 10.11 m.	417
		53·3	4 28	An uncommonly long narrow ray; E a full diameter of the field = 15′ long; 30″ broad; s v m b M; pos by ext 45° n p to s f.	58
		54·4	4 42	B; enormously long and very narrow. Pos of the long axis = 137°·4 by microm, very exact. A full diam of field = 15′ long, v s b M. I cannot divest myself of the idea of an appendage n of the nucleus running parallel to the lower edge, which seems more sharply cut than the upper. A fine object, but not *very* bright.	343
1358	Nova.	12 27 54·8	77 47 35	The n p of a fine double nebula; both F; R; g b M; pos 70° n p to s f; dist 1′.	191
		55·4	48 42	A curious bicentral nebula; both the component neb which run together are v F, v L, v g b M.	338
		56·0	49 34	v L; e F; like a v L double neb rubbed out; 4′ diameter	243
1359	Nova.	12 27 56·3	77 48 35	The s f of the double nebula	191
1360	III. 880	12 28 1·5	34 50 5	p B; irreg R; g b M; 20″. (Much out of place by working list.)	347
1361	I. 32	12 28 13·2	81 49 9	v B; m E; v s m b M, 2′ long; pretty bright arms and a resolvable centre.	117
		13·7	49 31	v B; S; m E; v s m b M	254
		14·4	48 55	p B; s b M	154
		14·7	48 54	v B; S; E; p s b M	251
		15·1	49 8	v B; S; v m E; v s b M; 30″1	250

No.	Synonym.	Æ 1830·0. h m s	N.P.D. 1830·0. ° ′ ″	Description and Remarks.	Sweep.
1362	III. 602	12 28 28·4	74 48 12	v F; p L; E; v g b M; attached like a tail to a star (place that of the ✱). (See fig 66.)	24
1363	IV. 8 } 9 }	12 28 32±	77 52 10	A fine double nebula. Both P B; L; R; v g b M; 60″ and 45″; pos estimated from diagram = 315° ±.	247
1364	III. 939	12 28 43·8	14 49 57	e F; only to be seen with very long attention	349
1365	II. 15	12 28 55·0	79 30 10	B; R; s m b M to a nucleus; a ✱ n p	120
1366	Nova.	12 28 55·5:	79 35 26	F; R; b M. Query, may not this be the same with II. 15, with a mistake of 5′ in P D?	19
1367	M. 91??	12 29 0±	75 17 ±	A bright ✱ 9 m, and 2 or 3 smaller; close by the B star and s p it, is a small well defined body which may be a close double star, and n p is also a F neb. The place set down is that of Messier's 91st neb, but I do not think this can be that object, whose existence even seems questionable.	243
1368	M. 58	12 29 3·6::	77 14 56	v B; irreg R; g b M; a B ✱ precedes ½ field	4
		5·4	14 54	B; R; g b M	22
		8·1	15 0	v B; v L; E; v s v m b M; r; 5′ l, 4′ br	247
		...	16 ±	v B; L; R; place only rough, being observed past meridian	242
1369	I. 124	12 29 8·9	83 42 0	v F; L; R; v g b M; 2′ diam	253
1370	III. 495	12 29 44·5	55 36 36	F; S; R; b M	74
		46·8	36 3	F; S; l E	131
1371	I. 125	12 29 46·4	84 44 45	p B; E	143
		47·3	44 45	p B; p m E; p s b M	141
1372	III. 504	12 30 35·2	83 2 34	No description	251
1373	II. 31	12 30 35·8	89 36 22	e F; L; p m E; v g l b M	145
1374	I. 273	12 30 40·2	14 52 17	B; R; p g m b M	349
		42·1	52 6	B; R; p g m b M; 30″; a S ✱ n p; dist 1′	348
		44·4	53 1	v B; R; p g m b M; 50″	382
		58·4	52 32	v B; l E; p g b M. The right ascension disagreeing so much with the rest, all the reductions have been carefully re-examined, but no error detected. Perhaps the moveable wire has been mistaken for one of the fixed ones in the obs of the transit, which will sometimes happen. (See Appendix.)	413
1375	II. 183	12 30 53·5	94 24 36	v s m b M, to a ✱ 11.12 m, with a faint chevelure	147
		54·6	24 21	p B; E; s b M to nucleus	234
1376	I. 43	12 31 10·9	100 40 19	v B; v m E, in pos 2° n p to s f; v s m b M to a nucleus; 5′ l, 30″ br, a B ✱ s p. There is a faint diffused oval light all about it, and I am almost positive that there is a dark interval or stratum separating the nucleus and general mass of the nebula from the light above (s of) it. Surely no illusion. (See fig 50.)	129
1377	II. 632	12 31 18·2	73 46 32	v F	24
		19·4	46 4	No description	422
		19·7	46 5	p B; L; R; g b M; 40″	419
		...	46 11	p B; p L; R; g b M; 30″	421

No.	Synonym.	R 1830·0.	N.P.D. 1830·0.	Description and Remarks.	Sweep.
		h m s	° ′ ″		
1378	I. 24	12 31 18·7	78 53 6	B; R; g m b M; has 3 small st, f	4
		19·5	53 37	B; R; b M; 30″	19
		19·5	53 25	B; S; R; p s b M; has 3 p B st f	191
		20·2	52 27	B; has a ✱ s f; Δ R A = 2ˢ ±	22
		21·1	52 28	B; R; p s b M; 3 stars near	120
1379	II. 577	12 31 41·7	85 56 38	Followed by 2 st 8 m, (*nisi* R A = 12ʰ 32ᵐ 12ˢ·9)	143
		43·0	56 41	F; S; R; precedes 2 st 9 m (*nisi* R A = 12ʰ 32ᵐ 13ˢ·2 — the observations leaving an ambiguity as to the wire employed).	141
1380	II. 184	12 31 53·9	94 11 56	F; L; E; v g l b M; 50″	234
1381	I. 254	12 32 22·1	27 26 55	B; L; v m E, in pos = 118°·6 (microm); g l b M; 4′ l, 1′ br.	344
1382	III. 43	12 32 22·2	77 9 19	S; E; 1 or 2 stars near or in it	192
		22·7	10 26	v F; a curious object; 2 or 3 v F st form a line with an oblique ray of neb.	245
		...	11 ±	v F; 2 or 3 v S stars in it	3
1383	II. 69	12 32 38·4	78 54 20	p B; R; p s b M; has ✱ 12 m 1′ n p, and a ✱ 5.6 m in field n f	120
		40·1	53 48	Almost stellar	22
1384	II. 20	12 32 49·4	81 45 1	F; R; p s b M; has ✱ 9 m 5ˢ f. Twilight	152
		53·6	45 24	p B; S; R; p s b M; 20″; a ✱ 8 m s f	117
		54·8	45 22	v B; S; R; p g b M; a ✱ 10 m 60″ f	250
		...	46 ±	Seen. P D roughly taken; no R A nor any description	154
		...	44 ±	p B; R; b M; has a ✱ f in parallel, ½ radius of neb from its edge. Rough P D.	254
1385	I. 178 179	12 33 19·9	47 54 52	Double; a B, L neb, g b M, with a large F one attached, 70° s f, so as to run together into one; ☾.	248
		20·4	55 58:	F; L; dimly seen in twilight	155
		21·9	54 18	No description	151
		23·5	54 32	F; L; R; b M	150
1386	M. 59	12 33 23·0::	77 25 28	B; irreg R; r	19
		27·0 ±	22 ±	F; R; g b M; 20″; has a ✱ n p and one s p. Place very rudely ascertained.	2
		28·4	24 53	v B; S; 1 E; v s v m b M; 2′ l, 1½′ br	338
1387	Nova.	12 33 25·7	76 7 15	v F; S; R; v g b M; 15″	247
1388	II. 411	12 33 27·1	58 60 25	p B; R; has a ✱ f Δ R A = 9ˢ·0	337
		29·6	59 47	F; R; 15″; a ✱ 9 m follows, pos = 301°·1; Δ R A = 8ˢ·0	331
		29·7	59 48	e F; has s f a ✱ 8.9 m; pos 30° s f by diagram	72
1389	II. 149	12 33 32·7	81 24 1	p B; E; p s b M	254
1390	Nova.	12 33 35·5	86 0 26	B; E. R A ill observed	142
1391	II. 659	12 33 40·6	56 29 46	a F neb n p V. 42, and almost close to it	74
1392	II. 660	12 33 42·6	47 46 32	F; S; R	150
		44·1	46 53	No description	151
1393	II. 772	12 33 45 ±	96 8 ±	v F; R; has another nearly n; dist 5′. R A by working list. P D rough.	147
1394	II. 773	12 33 47 ±	96 3 ±	R A by working list. P D rough	147

No.	Synonym.	Æ 1830·0.	N.P.D. 1830·0.	Description and Remarks.	Sweep.
		h m s	° ′ ″		
1395	II. 532	12 33 50·0	85 6 30	v F; v S; R	141
1396	I. 14	12 33 51·7	89 9 2	e F; R; g b M. Sky not clear.	145
1397	V. 42	12 33 53·1	56 31 36	v m E; a long ray which crosses the whole field, rather curved upwards (to s). Has a v F nucl and a B ✱ nearly in the parallel. A F nebula II. 659 is very near it, n p. (See fig 76.)	74
		55·0	31 17	Enormously long, extending across the whole field (15′). Nucleus not well defined. Is preceded by a ✱ 10 m, and that again by a S, F, R neb, forming a fine and very curious combination.	131
1398	III. 603	12 34 7·4	74 45 51	v F; v m E; v g b M	421
		7·8	45 55	v F; L; m E; v g l b M	419
1399	II. 38	12 34 8·4	86 22 28	B; R; b M; 30″	143
		10·2	22 44	B; L; R; v g v m b M, but not to a nucleus	238
1400	Nova.	12 34 9·7	69 7 51	v F; L; v g l b M; 2′ diam	334
		10·2	7 16	e F; L; b M; 3′ diam (an over-estimation)	61
1401	Nova?	12 34 10·2	85 22 21	v B; R; s m b M; 40″. If a mistake of 1° in P D be supposed in this obs, the place coincides with that of II. 38, and the descriptions agree.	142
1402	II. 70?	12 34 13±	77 39 12	F; R; g b M. My Father's P D is 77° 43′, if this be the same object.	3
1403	II. 125	12 34 18·8	75 48 50	B; E; has a ✱ 12 m s f; 1′ dist	247
1404	I. 10	12 34 40·2	87 4 53	B; S; l E; p s b M	143
1405	III. 44	12 34 53·0:	77 28 ±	v F. The preceding of the fine double nebula M. 60	22
		53·3	29 40	v F; p L; l E; the n p of 2	191
		53·9	29 53	v F; E about 20 or 30° from n p to s f; it precedes M. 60 about 2½′	19
		58·5	29 4	F; L; l E; 2′ diam. The n p of 2	338
1406	Nova.	12 34 53·3	33 54 30	e F; v S; R; g b M; 10″	347
1407	II. 794	12 35 0·3	34 12 30	Has 4 v S stars s p in a line	347
1408	M. 60	12 35 2·3	77 31 18	B; R; b M. The brighter of a fine pair, the other is v F; E 30° n p; 2½′ dist. (See fig. 74.)	19
		3·1	30 35	A double neb; a very fine and curious object. The p is v F the f v B; both large estimated dist of centres = 4′; pos 45° n p.	22
		3·9:	29 39:	No description	4
		4·1	31 10	v B; R; has a v F oval neb n p; pos 30° n p, dist 3′ by estim.	191
		6·5	30 49	B; R; v s m b M; 90″; the s f of 2	338
		...	31 ±	A most curious double neb 3′ dist centre from centre, but the nebulæ join with v F nebulosity. The fainter rather oval.	3
1409	II. 12	12 35 10·7	72 40 51	v B; R; v g b M; r; 30″	421
		11·7	40 47	Nearly R; g b M; r	27
		13·8	39 56	v B; L; E in parallel; g b M	25
		...	40 48	p B; E. No R A procured.	26
1410	I. 274	12 35 19·5	14 38 32	F; S; b M	348
		21·5	38 27	p F; S; R; p g b M; 15″. Among stars	349
		28·0	39 7	p F; S; R; 15″	382
		32·4	39 9	p F; S; R	413
		...	38 25	Follows a fine D ✱ of contrasted colours	170

Fig. 76.

Fig. 74.

No.	Synonym.	Æ 1830·0.	N.P.D. 1830·0.	Description and Remarks.	Sweep.
		h m s	° ′ ″		
1411	II. 126	12 35 22·2	75 56 44	v F; v L; 2′ l, 90″ br; 3 st near, l = 9 m	192
		24·7	57 46	v L; m E; 5′ l. Closer examined, it is a double nebula? near several stars, one of which = 8 m.	245
1412	II. 661	12 35 27·3:	48 2 46:	e F; near a * 15 m	335
		29·1	2 18	e F; almost stellar; has * 16 m f very near	151
1413	Nova.	12 35 27·9	30 6 26	not v F; p L; g b M. It is about 6′ dist n p two B st 8 and 10 m	345
1414	I. 176	12 35 39·3	56 53 46	A long nebulous ray pos = 34°·3 (microm). Its southern half is fainter than its northern. It meets *and cuts*? another neb. A strange object. See fig 75.	342
		39·9	53 55	The p and s of two neb which run together, not very bright	337
		40·0	54 14	The s p of 2 which run together or are connected by a narrow curve. Shape just made out through cloud.	341
		40·4	53 41	A very extraordinary object. Two nuclei (each g b M) joined by a long curved neck or isthmus of nebula.	74
		...	53 57	Two extended nebulæ crossing. They run together; the s p is v L; both p F. (N.B. in this obs they appear to have been well seen, and the nature of the object distinctly made out. A good diagram made.)	131
1415	I. 177	12 35 47·5	56 51 29	The s p of two which cross; p F. (See fig 75.)	341
		48·8	51 54	The neb intersected by I. 176	342
		49·9	51 10	The f of two which run together in a curve	337
1416	II. 127	12 35 57·3	75 33 42	F; R; b M; 30″	24
1417	Nova.	12 35 58·6	77 52 41	v B; S; v s v m b M almost to a *	247
1418	II. 643	12 36 15·6	51 56 5	p B; p L; R; b M; 40″	73
1419	I. 142	12 36 26·1	86 1 59	B; not v L; v s b M; has a * 10 m 45° s p dist 1′	141
		27·2	0 44	p B; p L; R; g b M; 20″; has a * 11 m pos 235°·5	238
1420	I. 15	12 36 26·8	89 31 37	p B; m E; p s b M; pos 45° n f or s p	145
1421	Nova.	12 36 41·6	77 37 39	B; S; R; p s b M; 15″	242
1422	III. 328	12 36 53·4	61 56 31	F; v S; R	64
		55·4	56 46	B; S; R; b M; r	66
		57·2	56 42	p B; S; R; g b M. The first of 2	417
		...	57 1	v S; s m b M to a * 10 m	65
1423	II. 774	12 36 59·5	96 8 11	F; R; p s b M	147
1424	III. 329	12 37 4·3	62 0 31	F; v S; R. There is evidently some error in this or the next R A, but it is probably this which is wrong, being observed at quitting the field, and the next being corroborated.	64
		15·2	0 32	p B; v S; the second of 2; Δ R A = 18ˢ·0	417
		...	2 ±	v S; s b M = a * 10 m; rough P D	65
1425	II. 326	12 37 49·9	58 20 14	e F; query if not bicentral; sky perfectly clear	341
1426	II. 181	12 38 33·9	91 48 17	B; not v L; p m E; p g b M	146
1427	III. 398	12 38 43·3	69 36 31	p B; S; resolved or resolvable. Has a * in centre	61
		43·4	36 42	S; stellar, or a * with a burr	63
		44·7	37 51	S; R; g b M; compact, almost stellar	334
1428	II. 795	12 38 54·8	34 31 20	p B; p m E; v s b M	347

No.	Synonym.	Æ 1830·0.	N.P.D. 1830·0.	Description and Remarks.	Sweep.
		h m s	° ′ ″		
1429	III. 543	12 39 11·9	84 44 11	vF; follows a star	142
		.....	44 ±	eF; 10ˢ following a * 9.10m	143
1430	Nova.	12 39 12·4	53 43 2	vF; R; psbM; 15″	331
1431	I. 128	12 39 13·9	75 18 46	eF; vL; E; 4′ l, 3′ br	338
		13·8	18 49	pB; vL; E; v diffused	242
		15·0	18 35	pB; vL; E; vglbM	247
1432	II. 182	12 39 25·7	92 23 57	B; pmE nearly in the parallel; gmbM; 90″ l, 60″ br	146
1433	II. 381	12 39 28·7 :	61 51 4	eF; hazy. RA imperfectly taken	67
		34·0	50 26	F; vS; R	64
		35·1	51 1	F; R; bM; (cloudy)	66
1434	II. 72	22 39 39·0	78 4 20	pB; R; gmbM	4
		39·8	5 5	F; S; R	191
		39·9	4 23	No description	22
		40·9	5 30	vF; R	19
		41·8	5 3	not vF; R	120
		42·2	5 16	pB; lE; psbM	245
1435	II. 796	12 39 47·6	34 41 30	vF; R; vglbM; 25″	347
1436	I. 39	12 39 48·9	94 52 6	vB; L; E; smbM to nucleus	147
		49·1	52 16	vB; lE; gmbM; 40″ l, 35″ br	234
1437	I. 129	12 40 14·0	97 44 25	vB; R; vsmbM to a fine resolvable nucleus, 40″. (Doubtless a globular cluster.)	137
1438	III. 524	12 40 15·6	100 28 6	pB; mE 50° nf to sp; a B * precedes	129
1439	II. 662	12 40 42·4	47 8 24	F; R; gbM; sky perfectly clear	151
		44·9	9 12	vF; S; R	150
1440	III. 610	12 40 56·5	94 16 16	vF; R. PD by MS 95°, but it was probably found by the working list, which makes its place 95° as from my Father's obs.	147
1441	II. 95	12 41 8·9	73 54 22	mE; 60″; a ray nebula 75° sp to nf; sbM to nucleus (by diag), a * f.	27
		9·2	54 31	vB; vmE; pos = 28°·5 by microm; bM; 90″ long	421
1442	Nova.	12 41 11·0	63 35 53	vF; pL	407
1443	II. 412	12 41 13·5	53 44 27	pB; E	131
		...	.....	Viewed; in field with a * 8 m; too F to take the place, owing to haze.	72
1444	I. 140	12 41 19·5	83 45 26	pB; L; lE; 60″ l. 50″ br: two st sf; 2′ dist	153
		19·5	45 57	pB; R; glbM; 80″	253
		20·5	45 26	F; L; R; gbM	152
		21·1	45 20	pF; L; lE; vglbM	250
1445	III. 536	12 41 26·9	102 24 47	pF; pL	351
		28·5	23 15	pF; S; R; gbM; 12″	352
1446	Nova.	12 41 47·1	94 21 6	eF; vS; between 2 st 5′ asunder	234
1447	III. 611	12 41 53·8	93 13 19	eF; bM	21

No.	Synonym.	R 1830·0. h m s	N.P.D. 1830·0. ° ′ ″	Description and Remarks.	Sweep.
1448	III. 424	12 41 55·9	55 54 45	e F; easily mistaken for a * 15 m	337
1449	III. 280	12 42 0·0	103 24 37	F; R; the n p of two, 1′ distant	351
1450	II. 298	12 42 3·4	103 25 7	F; R; the s f and brighter of 2 dist 1′	351
1451	I. 84	12 42 3·6	63 34 23	v B; v L; a v B nucleus in a wide, F, oval atmosphere, 4′ l, 3′ br	407
1452	I. 41	12 42 12·5	95 28 16	v F; p L; E; third class; sky perfectly clear and fine.	147
1453	II. 73	12 42 31·0:	78 10 0	e F; L	19
		32·6:	10 12	p F; p L; irr R; b M; r	4
		32·8	9 26	F; R; has a * 12 m immediately p	22
		34·7	9 24	F; m E in parallel by diagram; has a * near the centre and another at the p end. (N.B. The MS makes the minute of R A 43; but it is *possible*, from the discrepancy of the descriptions, that it may be a different nebula, but this is unlikely.)	192
		...	10 32:	v F; E	3
1454	Nova.	12 42 33·7	84 13 25	v F; v S; R	141
1455	III. 515	12 42 47·5	97 29 20	F; L; R; v g l b M	137
1456	M. 94	12 42 51·9	47 57 2	v B; L; v s m b M, almost up to a nipple-like nucleus. Not resolved, but strong twilight. (See fig 41.)	155
		51·4	56 28	B; L; R or l E; s m b M to nucleus 15″ in diam and = a * 8 m, well defined, but not stellar. The nebula 2′ diam.	248
		52·0	56 26	e B; R; v s v m b M to a nucleus = in its impression on the eye to a * 9 m, but which will not bear illuminating more than 11 m; diam of neb = 2½′.	335
		52·2	56 42	v B; R; p s v m b M, to a nipple; with 240, r; glimpses of stars seen. A fine object. 90″ or 2′ diam.	150
		52·9	56 51	The central B part (10″ diam) equals a * 9 m, e compressed	151
		...	.....	Viewed. v B; v s m b M; 4′ diam. Not resolved but resolvable. (A very interesting object, being a neb v s m b M on a great scale.)	73
1457	III. 496	12 42 52±	54 55 25	e F; R A from working list	337
1458	III. 721	12 43 6·8	41 24 6	v F; R; p s b M	329
1459	III. 537	12 43 21·1	102 28 58	p F; S; R; g b M; 12″	352
1460	Nova.	12 43 21·9	77 0 5	p B; m E; r	247
1461	I. 16	12 43 39·3	90 16 37	B; R	146
1462	I. 25 = II. 74	12 43 42·8	77 45 45	R. (There is no doubt of the identity of the nebulæ I. 25 and II. 74.)	191
		44±	44 ±	F; R; g b M; 20″. (Viewed.)	2
		44·7	46 14	B; R; p s b M	192
		45·3	45 41	v B; v L; p s b M; r; 2′ or 3′ diam	245
		45·6	45 34	p B; R; p s b M; two small stars point to it	243
1463	IV. 78	12 43 54·9	16 11 49	p F; L; R; 40″; the central portion up to diam 30″ is nearly uniform, so as to give it an approach to the appearance of a planetary nebula.	382
1464	III. 281	12 44 1±	104 29 ±	Seen in its place by working list. P D roughly taken. R A from list.	351

Fig. 41.

No.	Synonym.	R 1830·0.	N.P.D. 1830·0.	Description and Remarks.	Sweep.
		h m s	° ′ ″		
1465	III. 70	12 44 16·2	73 13 36	v F; m E	421
		16·3	13 20	e F; p L; R	419
		16·4	13 32	e F	27
1466	II. 75	12 44 20·9	77 50 55	p B; v m E in pos = 34°·0 by microm. Remarkably situated under a canopy as it were of 3 bright stars. (See fig 84.)	191
		22·2:	49 44:	A ray b M almost to a nucleus under an arch or roof of 3 stars 10, 11, and 12 m.	4
		23·4	51 14	p B; m E; under an arch of 3 st	243
		24·9	51 24	v m E; under 3 stars; II. 74 precedes. The eye is led down to it by two smaller st which continue the arch.	192
		...	49 ±	F; E; b M; 30″ l; under 3 stars. Rough P D	2
1467	III. 544	12 44 35·0	84 37 10	p B; S; R; g b M; 20″	141
1468	II. 535	12 44 41·3	87 48 37	F; m E; follows a * 9 m in parallel; sky not quite clear	145
1469	II. 24	12 44 49·7	86 53 56	B; s m b M; R; 1′ diam	142
		51·7	54 9	p B; R; g p m b M; 18″; (	238
		...	56 ±	F; R; g b M; sky turbid; (rough P D)	145
1470	II. 186	12 44 56·7	95 41 46	v F; L; R; 90″; v g l b M. Its companion looked for but not seen	147
1471	III. 618	12 45 0·6	52 15 17	e F; S; R; b M. Sky perfectly clear	331
1472	III. 106	12 45 17·4	79 22 1	e F; p L	19
		17·6	21 38	v F; R	22
1473	II. 345	12 46 0·5	62 0 11	F; R; 1′ s of a * 9 m	64
		2·1	0 9	A neb attached to a B * 1′ n, place that of the nebula	67
		3·7	.....	No P D taken nor any description	68
1474	II. 21	12 46 25·1	81 1 4	B; R; p g b M; 30″; a v S * included, f	117
		29·4	1 11	No description	152
		30·2	1 7	p B; R; p s b M. Among several stars	253
1475	I. 93	12 46 26·3	60 8 1	not v B; l E; has * 8 m 1′ dist 80° n f	65
		27·0	8 9	p B; S; E. Query if not bicentral. Near a * 9 m	341
1476	III. 548	12 46 36·2	86 10 30	F; S; close to a *	141
1477	II. 382	12 46 38·7	61 39 26	p F; R; g b M	343
		39·4	39 37	p B; R; g b M; 40″. Minute mistaken, in R A; corrected by comparison with Sw 343 and working list.	417
1478	I. 211	12 46 46·1	42 33 19	p B; R; 40″; has a * 15 m p	255
		...	.....	B; R; p s b M; 30″; a * 13 m near n p. P D too roughly taken (being much past the meridian) to be of any use.	140
1479	III. 816	12 47 6·1	35 58 40	e F	347
1480	I. 141	12 47 22±	84 47 ..	not B; E; g b M. Sky quite clear	142
		...	.....	F; R; b M; sky perfectly clear	143
1481	II. 383	12 47 42·2	61 20 1	e F	64
1482	II. 777	12 47 46·9	95 53 41	S; R; b M; wind violent	147
1483	I. 243	12 47 51·3	30 44 27	p B; S; R; g b M; 18″	345
		55·1	44 32	p B; L; l E; v g b M; 90″ l, 75″ br	323

No.	Synonym.	R. 1830·0. h m s	N.P.D. 1830·0. ° ′ ″	Description and Remarks.	Sweep.
1484	II. 549	12 48 0·0	97 36 47	p B; p L; 1 E in merid; v g b M	137
1485	II. 384	12 48 21·4	61 54 4	v L	67
1486	M. 64	12 48 21·5	67 24 0	B; v L; v m E; v s m b M; well examined. I am much mistaken if the nucleus be not a double star, in the general direction of the nebula: 320 much increases this suspicion; 240 shows *well* a vacuity below (n of) the nucleus. The neb is 8′ or 9′ long, and 2′ broad.	424
		22·4	23 10	v L, oval neb, with a v S, s B, vivid nucleus. The neb is far feebler; 6′ l, 4 or 5′ br. I see no "dark recess" in it.	409
Fig. 27.		26·1	23 17	B; L; E, 5′ l, 3′ br; v s v m b M, almost to a ✱, but magnifying destroys this effect. Resolvable but not resolved.	246
		...	.....	Viewed, and the appearance of a vacuity below the nucleus verified. April 21, 1833, a careful drawing taken. (See fig 27.)	
1487	II. 346	12 48 39·0::	62 4 46	v F; p L; 35″	65
1488	III. 817	12 48 50·7	36 46 58	e F; R; S; b M	328
1489	Nova.	12 49 1·6	40 16 26	A rather doubtful object; haze	329
1490	Nova.	12 49 8·2	102 8 10	v F; has 3 small stars s p	352
1491	II. 536	12 49 10·7::	87 30 37	F; p L; E; v g b M; has a ✱ 30° n f	145
1492	III. 613	12 49 14·9	92 41 40	F; l E; has a ✱ 30″ dist, 45° s f, 12 m	146
1493	II. 387	12 49 17·9	60 36 22	p B; R; a v S star makes it elongated	417
		18·7	36 8	p F; double, n f, dist 20″	343
1494	II. 386	12 49 28±	61 40 6::	F; R; R A by working list	68
1495	Nova.	12 49 44·3	51 42 17	e F	331
1496	II. 385	12 50 21·0	61 28 52	p F; v S; R; s b M; 10″	417
		21·8	28 26	v F; R; p s l b M; 20″	343
1497	I. 68	12 50 25·3	104 7 47	p B; R; s b M; 25″	351
		25·3	7 33	p B; R; p s b M; 20″; a ✱ 13 m pos 140°; dist 1 diam by diag	352
1498	I. 162	12 50 58·1	74 54 40	B; E from s p to n f; s m b M; has a ✱ involved, p its centre, in the parallel.	23
		58·3	54 40	B; m E; s b M, to nucleus; has a S ✱ n p	419
		58·5	54 12	B; E in parallel; s b M to nucl; 2′ l, has a ✱ in it 15 m, 10° n p the nucleus.	24
		58·7	54 41	B; m E; s b M. The ray passes through a S ✱	421
		59·2	54 30	p B; v m E; s b M; has a ✱ or 2 14 m near	247
		60·4	55 4	B; v m E in parallel; has ✱ 12 m, 3″·0 p, at the n edge of neb.	338
1499	IV. 30	12 50 56·6	54 13 33	F; S; R; much doubt as to nature of the object. Haze	72
		57·9	12 58	An e F nebulous ray (pos about 30° by diag) connects 2 stars 10 and 12 m by obs. The minute of R A is 51, but this is probably a mistake in reading the chronometer.	337
Fig. 62.		61·6::	17 ±	a v F neb; E n f to s p, between 2 stars, the southern of which is ill defined. Both seem to belong to the nebula. Place very ill determined, the P D especially being a mere estimation from a v distant ✱. (See fig 62.)	131
1500	Nova.	12 51 14±	61 7 ±	The first of 5 south of a ✱ 7 m. Place by configuration with the others.	343

No.	Synonym.	R 1830·0.	N.P.D. 1830·0.	Description and Remarks.	Sweep.
		h m s	° ′ ″		
1501	II. 388	12 51 21·4	61 8 1	F; S; R	65
		23·5	8 31	v F	64
		...	8 ±	The second of 5, south of * 7 m	343
1502	II. 389	12 51 33±	61 7 ±	The third of 5; place by configuration	343
1503	III. 83	12 51 38·8	76 36 10	F; v L; R; v g b M; 2′	245
		39·7	36 54	v F; p L; R; v g l b M	192
1504	Nova.	12 51 44·2	95 56 6	v F; v S; E	234
1505	II. 778	12 51 46·9	95 9 16	p F; v S; E; p s b M	147
1506	III. 64	12 51 51·3	93 40 19	v F; R; b M	21
1507	II. 391	12 51 54·5::	61 5 21:	No descrip. The R A very loosely determined	64
		59·6::	5 58	B; p m E; b M. The fourth of 5, s of * 7 m	343
1508	II. 390	12 52 1·1	62 11 19	e F	68
1509	I. 143	12 52 1·9	86 35 30	A * 10 m, has an oval neb attached, 45° n p. (See fig 67.)	141
		2·4	35 18	A * 10.11 m, with an oval brush n p	143
		...	35 ±	A star 11 m, with a fan or brush	142
1510	Nova.	12 52 2·7:	61 8 1:	B; S; R; in parallel with another which it follows	65
		...	7 ±	The last of 5, south of a * 7 m; more suspected to the south	343
1511	I. 69	12 52 3·4	103 36 12	p F; R; near some stars	351
1512	Nova.	12 52 13·5	41 52 6	p F; S; R; 10″; g b M	329
1513	IV. 47	12 52 39·9	93 37 39	p B; R; g b M; nothing very remarkable	21
		...	39 ±	R; rough P D, taken past meridian	147
1514	II. 645	12 52 45·3	51 44 2	e F; s f a * 17 m, (1 radius from edge by diagram)	331
		46·3	45 3	p B; v S; s m b M	73
1515	Nova.	12 53 5·2:	41 52 8	e F; S; E; b M	140
1516	II. 393	12 53 12·5	61 12 14	F. There are several more in the neighbourhood	67
		...	11 52	F; p L; 40″	417
1517	II. 300	12 53 15·9	104 3 37	v F; R; b M	351
		16·3	3 16	v F; irreg R; v g l b M. (N.B. My Father has two observations of this nebula; both agree in making the P D 103°, but mine are both correctly reduced, and there is no appearance of any mistake.)	352
1518	II. 394	12 53 16·0	61 15 4	v F; one of several. (N.B. One of these must have been II. 392, which is said to precede 393 and 394, dist 8′.)	67
1519	II. 779	12 53 17·9:	96 48 0	v F; R A doubtful	137
1520	I. 40	12 55 25·7	94 38 31	p F; L; v g b M; E; 60″1	234
		26·5	38 51	F; R; b M; sky very clear	147
1521	Nova.	12 55 28·9	37 45 38	e F; R; p s b M	328
1522	II. 395	12 55 39·4	60 54 0	F; R; b M; has * 9 m 45° n f; 1′ dist	68
1523	II. 188	12 56 17±	95 35 36::	v F; R; sky very clear. Wind. R A by working list; P D inaccurate.	147

No.	Synonym.	R 1830·0	N.P.D. 1830·0.	Description and Remarks.	Sweep.
		h m s	° ′ ″		
1524	II. 396 = III. 303	12 56 46·6	59 57 31	v F; S; R. (N.B. The nebulæ II. 396 and III. 303 are no doubt identical.)	64
		49·0	58 9	v F; R; III. 303 looked for and suspected; minute in R A = 57 by obs; but this is an evident mistake.	341
		50·0	57 41	B; R; s m b M to a * = 11 m	65
		51·0	57 58	p F; S; p s b M; 12″	342
		55±	57 35	Barely visible in twilight. The R A very uncertain from fluctuating zero. (There is also an obs in Sw 341, which may perhaps refer to this nebula; but the minute is wrong, and it is described as "suspected" but not sure.)	259
1525	II. 413	12 57 0·3	53 54 45	p B; R; s b M; 25″	337
		3·1	54 32	p B; R; p s b M; 25″	331
1526	II. 397	12 57 0·5	61 31 7	F; R	67
1527	Nova?	12 57 30·1	13 41 13	v F; S; R; g b M; 12″. (The place is within barely possible limits of III. 937.)	348
		38·3	40 37	v F; R; v g b M	349
1528	Nova.	12 57 37·2	55 54 51	e F; S; R	74
		...	54 ±	e F. Seen in its place as determined by former sweep	337
1529	II. 398	12 57 37·9	61 21 17	F; irreg fig; b M	68
1530	II. 663	12 58 3·4	47 21 22	v F; R; S; 15″	248
		5·9	21 38	F; e S; stellar; 5″; has a v S * near it, to s	151
1531	III. 304	12 58 7·4	60 2 22	v F; R; g b M; near a double *	417
		10·7	2 9	F; l E; v g l b M; pos from the double * h 2626 = 34°·9 by microm.	342
		...	3 ±	v F; l E; pos from a * 7·8 m = 44°·0	343
1532	III. 779	12 58 12·3	32 46 17	e F; S; l E; a sure obs	345
1533	III. 783?	12 58 17·8	35 31 0	Either a v F neb and star attached, or a nebulous double star, a doubtful object. The R A differs materially from that of my Father's III. 783.	347
1534	Nova.	12 59 3·8	94 6 21	v F; v S; R; p s b M; 10″	234
1535	Nova.	12 59 28·6	70 40 16	v S; R; s b M; stellar	61
		30·2	40 41	F; v S; R; p s b M	334
1536	II. 301	12 59 57·9	104 36 32	B; R; p s b M; 30″	351
		58·2	35 34	v B; R; p s b M; sky remarkably fine	352
1537	II. 189	12 59 58·9	95 51 56	F; p L; R; 50″; has * 9 m, 80″ dist s f	147
1538	III. 401	13 0 26·5	53 53 12	e F; S; R	331
		27·6	53 47	F; S; R; b M	131
1539	III. 654	13 0 28·1	47 25 18	v F; v S; R; 10″	151
1540	I. 42	13 0 30·4	96 56 0	Not v F; R; v g b M; 40″; has a * 8 m, n p	137
1541	Nova.	13 0 36·5	77 27 22	v F; S; l E; north of 2 small **s**	338
1542	Nova.	13 0 36·7	37 9 13	p F; S; R; 8...10″	328
1543	II. 537	13 1 1·2	87 25 57	e F; R; l b M; sky not perfectly clear	145
1544	II. 366	13 1 39·7	60 11 1	F; l E	65

No.	Synonym.	R 1830·0. h m s	N.P.D. 1830·0. ° ′ ″	Description and Remarks.	Sweep.
1545	Nova.	13 2 20·9	35 34 50	not v F; S; irr R; g b M	345
1546	III. 305	13 2 54·9	59 26 31	e F; v S; R	64
		61·7::	27 35	F; R; distinctly seen in twilight, but R A doubtful to the extent of 10ˢ.	259
1547	I. 96	13 3 5·0	52 1 24	v B; v L; m E; 4′ l, 1′ br; v s b M to a nucleus, pos by diagram = 30° n f to s p.	73
		5·2	1 40	v B; m E, in pos 20° n f to s p by diagram; s m b M; 2′ long.	72
1548	Nova.	13 3 15·2	104 53 33	v F; R; b M; a * 10 m 45° n p, dist 5′	352
1549	I. 85	13 3 21·4	66 10 15	v F; L; double or wedge-formed bicentral; pos 17°·0 per microm. Each neb v g l b M; a large * (the first of a trapez) 24ˢ f.	409
		21·8	11 15	not v B; E; g b M; 50″; has a * 9 m 23ˢ foll, the first of a trapezium.	424
1550	III. 820	13 3 27·2	39 0 16	e F; R; s p a * 15 m	329
1551	II. 414	13 3 38·6	52 49 7	p B; S; p m E; p s b M	331
1552	II. 637	13 3 42±	93 26 26::	No description. R A by working list	147
1553	III. 669	13 3 52·8	105 51 16	v F; R; b M	354
1554	II. 746	13 3 54·6	108 36 28	B; R; p g m b M; 30″	355
1555	III. 545	13 4 5·4	84 21 31	e F; S; R	142
1556	II. 129	13 4 12·4	76 29 54	v F; R; p s l b M; 50″	338
		12·8	29 59	L; R; straggling borders; p s m b M	242
		13·8	29 44	F; p L; E; 30″ long	192
1557	Nova.	13 4 26·3	42 54 25	p F; R; 40″; has a * 12 m 1½′ n f	255
1558	M. 53	13 4 32·3	70 55 26	A most beautiful highly compressed cluster. Stars very small, 12 . . . 20 m; with sc st to a considerable dist; irreg R, but not globular. Comes up to a blaze in the centre; indicating a round mass of pretty equable density.	25
		33·4	55 38	extremely compressed. A most beautiful object	26
		33·5	55 32	Seen by Mr. Baily. A fine compressed cluster, with curved appendages like the short claws of a crab running out from the main body.	63
		34·6	55 6	A mass of close-wedged stars 5′ in diam; a few = 12′m, the rest of the smallest size and innumerable.	61
		35·1	55 33	Observed with Mr. Baily	62
		...	.....	Viewed. A most beautiful cluster	334
1559	II. 664	13 4 32·9	45 3 24	F; m E; 70° n f to s p; 90″ l, 20″ br	151
		37·0	2 53	F; a long ray 3′ l, 20″ br; v l b M	140
1560	III. 649	13 4 43·5:	57 17 49::	Obs somewhat doubtful. The P D may err 2′, as clouds prevented verification.	341
		46·0	17 11	e F; R; has a * 14 m to n	74
		46·5	16 57	v F; E; S; 30″ s of a * 13 m	131
1561	Nova.	13 4 45·6	83 1 58	v F; R; g b M; 20″	251
		46·4	1 59	e F; R; v g b M	250
1562	Nova.	13 5 7·7	42 1 3	F; R; g b M; 15″; twilight	257

No.	Synonym.	Æ 1830·0.	N.P.D. 1830·0.	Description and Remarks.	Sweep.
		h m s	° ′ ″		
1563	III. 367	13 5 18·1	61 18 1	F; not v S; R	65
		22·2::	17 48:	e F; irr R. Sky growing thick	343
1564	I. 97	13 5 35·2	52 29 38	B; p m E; s m b M; a * n p	72
		37·6	30 32	a v B nucleus with F branches, position = 166°·8 per microm.	331
1565	II. 510	13 5 57·3	105 41 52	p F; R; b M; 25″. A * 12 m 1′ n p	354
		57·4:	41 3:	No description	157
1566	II. 511	13 6 21·4	105 29 15	p F; p L; R; 30″	354
1567	Nova.	13 7 34·9	59 24 9	v F	342
1568	II. 513	13 7 55·5	105 44 13	v F; R; 20″	354
1569	VI. 7	13 8 2·4::	71 25 41	v L; e F; a cluster of stars 19 or 20 m, with 4 or 5 = 15 m; irreg R; v g v l b M; diam at least 8 or 10′. A most curious and interesting object. The stars are just discernible. So faint, might easily be overlooked. R A of working list very much out, by reason of which the obs was nearly lost and quite spoiled.	334
		...	25 32	v F; v L; 7′ diam; v S stars 15 .... 20 m. Its true R A much *precedes* that in the working list.	27
1570	M. 63	13 8 10·9	47 4 12	B; p m E; v s m b M, almost to a * pos 30° n p to s f. The s f end more diffused. Has a B * n p and a D * f.	151
1571	III. 306	13 8 13·3	58 8 36	F; S; R; b M. The first of 2	74
1572	III. 307	13 8 27·7	58 3 43	F; S; R; b M. The second of 2	74
1573	III. 308	13 9 32·8	58 0 30	v F	342
1574	III. 282	13 10 19·4	103 57 22	v F; p L; E	351
1575	III. 309	13 10 31·6	57 37 45	e F	342
1576	III. 117	13 10 32·0	101 49 45	v F; S; R; 15″; the s p of 3	352
1577	II. 193	13 10 34·5	101 45 2	B; R; s b M; 20″; the northern and second of 3	352
1578	III. 118	13 10 41·1	101 48 12	v F; p L; 1 E; 40″; the f of 3	352
1579	II. 313	13 11 5·3	110 55 7	B; R; p s b M; 35″	355
1580	II. 327	13 11 37·5	58 51 21	p B; p L; g b M	65
		39·7	52 45::	No description	259
1581	II. 539	13 11 46·9	103 11 22	p F; S; R; g b M; 15″	351
1582	Nova.	13 11 51·9	91 24 37::	v F; R; g b M. It is 40° n f a * 11 m.	146
1583	III. 633	13 11 59·0	48 41 53	v F; R; b M; 12″	155
1584	III. 650	13 12 15·5	56 1 31	F; S; R; b M; the s p of 2	74
		...	.....	Viewed. e F	337
1585	Nova.	13 12 23·2	55 58 1	F; S; between 2 stars; the n f of 2	74
		...	57 30	e F	337
1586	III. 619	13 13 44·6	50 32 54::	v F; 1 E; 30″1	155
1587	III. 119	13 13 57·4	102 5 12	not v F; R. Nearly lost by looking too late, the R A of the working list being too great.	351
		58·3	3 58	F; R; g b M; 20″	352
1588	II. 826	13 14 3·4	31 27 32	v F; p m E; 30″	345
1589	II. 646	13 14 16·9	50 22 1	v F; L; R; v g l b M; 2′	73

No.	Synonym.	Æ 1830·0.	N.P.D. 1830·0.	Description and Remarks.	Sweep.
		h m s	° ′ ″		
1590	III. 368	13 14 52·9	62 8 22	Not v F; p m E; 1 b M; 30″ l; pos 40° inclined to the parallel..	417
		54·7	7 38	Not v F; irreg fig; v g b M; sky rather dull.....	343
1591	III. 925	13 14 54·0	82 43 6	F; R; g b M; 20″.....	152
		...	45 ±	F; R; g b M; 30″. P D only rough, being taken much past meridian.	153
1592	Nova.	13 14 54·2	60 47 11	v F; L; makes an equilateral triangle with 2 stars 11 m, n p..	65
1593	Nova.	13 15 33·1	79 23 40	Not v F; S; R; g b M.....	120
1594	II. 666	13 15 40·4	46 1 16	F; R; g b M; 35″.....	151
1595	II. 653	13 15 45·5	75 7 40	F; R; g b M; 15″; a D * follows 7ˢ·5	420
		47·4	8 7	p B; R; not v s b M; a coarse D * follows.....	338
		48·7	7 44	p B; R	192
1596	II. 328	13 15 50·2	57 32 38	p B; R; g b M. No other near	74
		52·5:	33 17	p B; R; follows a D * of the third or fourth class.....	259
		...	32 30	p B; p L; s f a small group of stars 13 m	342
1597	II. 314	13 16 6·3	110 13 55	F; p L; 1 E; v g b M.....	355
1598	III. 84	13 16 31·0	75 21 54	e F; R; S; p s b M; 15″	192
		...	.....	Viewed; v F; R; b M; 15″.....	338
1599	III. 402	13 17 7·2	52 43 37	v F; R	71
		8·6	43 42	p F; R; v s m b M to a *. Has a * 12 m preceding. The s p of 2 nebulæ.	331
1600	III. 403	13 17 17·7	52 40 1::	p B; R; the n f of 2	71
		18·1	42 37	p F; R; v s b M to a *.....	331
1601	II. 25	13 17 38·7	86 61 1	F; 1 E; v s m b M to a * 12 m; 30″	145
		41·3	59 56	B; R; p s b M; 30″	142
1602	II. 667	13 17 45·9	45 51 12	Not v F; R; g b M	151
1603	Nova.	13 18 20·5	72 14 30	v F; R; has a * 7 m, 6′ north	420
		22·1	14 32	e F; S; R; has a B * n f.....	27
1604	III. 404	13 18 25·5	53 10 23	p B; b M; the s p of 2	72
		26·3:	10 27	Not v F; E; g b M; 40″; the s p of 2.....	331
1605	III. 405	13 18 45·3	53 7 38	v F; the n f of 2.....	72
		45·8:	6 54::	e F; L; R; it is 45° n f III. 404	331
1606	III. 651	13 19 25·3	57 5 36	e F; R; 30″	74
		26·1	4 40	Not v F; p L; E; the p of 2, very similar	337
		27·5	5 7	F; R; b M.....	131
1607	Nova.	13 19 32·4	71 20 8	v F; R	26
1608	Nova.	13 20 23·6	57 4 55	Not v F; p L; E; the following of 2, very similar	337
		23·8	5 36	p F; R; b M; 30″.....	74
		25·5	5 7	p F; E; 1 b M.....	131
1609	III. 784	13 20 27·3	33 37 40	v F; R	347
1610	V. 22	13 20 40·8	107 5 26	F; v m E in pos 128°·8 by microm; p g b M; 180″ l, 30″ br..	354
		41·2	4 48	F; L; E; v g b M; twilight.....	157

No.	Synonym.	R 1830·0.	N.P.D. 1830·0.	Description and Remarks.	Sweep.
		h m s	° ′ ″		
1611	III. 672	13 20 51·8	42 28 59	v F; R; 50″	255
1612	III. 45 } III. 46 }	13 20 59·4	78 6 44	v F; two close together, or one E nearly in merid. A star 11 m n	242
		60·3	6 40	e F; E; involves a * at the S end, and has a * 6 m, 15′ s and a few seconds preceding.	120
1613	Nova.	13 21 0·0	72 3 45	F; p L; R; p g b M; 40″	420
		1·9	4 8	F; p L; R; v g b M	26
1614	Nova.	13 21 11·3	42 31 49	p F; R; v s b M; almost stellar	255
		12·3	32 19	p B; R	256
1615	III. 70	13 21 9·4	72 17 37	v F; has either a star excentric or a double nucleus	27
		...	17 35	F; S; R; 15″; has a * 7 m nf, 8′ dist. No R A procured	420
1616	Nova.	13 21 19·8	75 48 44	e F; R; 20″	338
		21·3	49 5	F; R; S; 15″	247
1617	II. 679	13 21 22·4	90 50 37	F; l E; g b M; 20″; the first of 2	146
1618	II. 680	13 21 27·4	90 46 42	F; nearly R; g b M; 30″; the second and brighter of 2	146
1619	III. 642	13 21 40·7	75 42 19	e F; R; 25″. (Seen also in Sw 192.)	338
1620	III. 652	13 21 58·0	57 59 17	v F; R; g l b M; 15″	342
		...	59 16	F; R; b M; much past merid, and no R A to be procured	74
1621	Nova.	13 22 22·8	70 59 21	p F; R; g b M; 20″; a coarse triple * f	334
		22·9	58 36	v F; S; b M; has a considerable triple * following, dist = 8′.	61
1622	M. 51	13 22 37·1	41 56 9	A very bright round nucleus surrounded at a distance by a nebulous ring. (See fig 25, and the Note on this neb in the Appendix.)	255
		38·5	56 13	A most astonishing object, &c. (See Appendix as above.)	140
		38·9	54 53	A nucleus and double or divided ring, &c. &c.	257
		40·0	55 36	Place of the nucleus. The rings barely discernible for a haze.	329
		41·5	.....	p B; E; v g b M; seen through cloud	138
		43·8::	57 28:::	(See Appendix.)	256
1623	I. 186	13 22 46·0	41 51 ±	B; R; v s b M to a *. This nebula is the companion of M. 51 and is figured with it.	140
		47·0	51 16		329
		50·0	.....		138
		50·3	52 18		256
1624	III. 406	13 22 58·8	54 17 45	No description	337
		60·5	16 37	No description	71
1625	IV. 63	13 23 4·3	30 42 12	p B; irreg R; g b M; 90″; r; no nucleus seen	345
1626	III. 643	13 23 53·5	75 13 34	A F oval wisp attached to a * 11 m	192
1627	III. 9	13 23 55·4	81 48 17	F; S; R	253
		56·3	48 26	F; S; R; p s b M; 10″; almost stellar	152
		57·9	48 57	F; R; like a * with a burr; the first of 2	250
		...	48 ±	Seen in its place; p B. No R A observed	251
1628	III. 10	13 24 12·1	81 47 37	F; S; R	253
		13·4	48 27	F; R; s b M; 15″; like a burred *. The second of 2	250

No.	Synonym.	Æ 1830·0.	N.P.D. 1830·0.	Description and Remarks.	Sweep.
		h m s	° ′ ″		
1629	III. 99	13 24 18·1	81 56 57	F; S; R; p s b M; 15″	153
		...	58 ±	F; not v S; R; p s b M. (Past merid.)	152
1630	Nova.	13 24 21·8	90 9 32	p B; S; R; v s m b M; 20″	145
1631	Nova.	13 24 51·8	81 49 47	e F	253
1632	III. 656	13 25 26·0	47 15 18	v F; R; g b M; 30...40″	151
1633	III. 926	13 25 37·0	82 38 32	A * 9 m with a F, very dilute nebulous atmosphere. (Possibly the minute of R A should be 26.)	153
1634	Nova.	13 25 51·1	71 16 8	v F; S; R; b M	26
1635	Nova.	13 26 12·6	26 24 36	R or l E; g b M	411
1636	II. 841	13 26 19·1	26 21 26	Not v F; p L; R; g b M; 35″	411
1637	III. 86	13 26 35·9	75 17 31	e F; R	338
		36·4	19 35	F; R; p s l b M; 25″	247
1638	III. 85	13 26 36·2	75 23 4	v F; S; R	192
		36·4	22 38	p B; S; R; s b M; 30″	247
		37·3	23 29	v F; R; v g l b M; 20″	242
1639	III. 87	13 26 36·9	75 28 11	v F; R; g l b M; 20″	338
		...	28 0	v F; R; p L; R A not observed, but P D taken in time	192
1640	III. 407	13 26 43·0	54 25 57	F; S; R; has a * s p	131
		45·4	25 18	F; S; g b M; 15″; has * 10 m 30° s p, dist 40″	72
		45·9	25 27	F; R; b M. A star very near	71
1641	III. 928	13 26 52±	87 44 ±	v F; R. R A by working list; past merid.	145
1642	III. 408	13 26 54·9	54 19 53	F; S; R; g b M; 15″	72
		55·9	20 17	F; R	71
1643	Nova.	13 27 3·5	75 26 28	F; L; E; v g b M; 50″ l, 45″ br	247
1644	III. 100	13 27 26·0	82 31 2:	F; p L; R; very dilute; n f a * 9 m	153
		28·2	32 34	The faintest thing imaginable	251
		30·2	33 1	v F; S; R	253
1645	III. 425	13 27 30·3	54 27 32	F; S; R; has a v S * near	131
1646	III. 101	13 27 57·9	81 45 29	v F	250
		...	46 ±	v F; R; 25″. No R A taken; past merid.	153
1647	Nova.	13 28 29·7	86 21 33::	e F; v L; fills the whole field. Strongly suspected; yet a doubt remains.	143
1648	III. 620	13 28 44·2	50 46 26	p F; E or obscurely bicentral; l b M, pos of elongation 25° n f by diagram.	73
		45·7	47 49::	v F; p L; l E. P D probably erroneous from a shifting of the microscope.	155
1649	II. 297	13 28 52·8	107 0 50	v F; v L; p s b to a brighter kind of nebula; a good type of its class. It loses itself quite imperceptibly. Diam of the faint neb = 2′; of the brighter part or nucl = 10 or 15″. (See fig 39.)	354
		53·5	0 48	v F; p L; g b M; 40...50″	157
1650	I. 34	13 29 5·5	80 14 18	p B; v L; E, 60° n p to s f; p s b M; 3′ l, 2′ br	120

Fig. 39.

No.	Synonym.	R 1830·0. h m s	N. P. D. 1830·0. ° ′ ″	Description and Remarks.	Sweep.
1651	III. 72	13 29 20·6	73 9 8	e F; S; R; b M	26
		21·0	9 15	p F; R; 25″	420
		21·6	9 17	v F; S; R	27
1652	III. 369	13 29 29·1	61 42 31	v F; R; S	65
1653	III. 505	13 29 50±	84 37 1	F; R; b M; 30″. No R A taken, but inserted from working list	142
		...	36 ±	e F; S; R; rough P D. R A per working list	143
1654	II. 895	13 31 13·7	88 17 43	The first of 2 composing a double nebula; both v F; R; b M. The smaller of the two.	145
1655	II. 896	13 31 18·2	88 18 3	The second and largest of 2, composing a double nebula	145
1656	III. 673	13 31 18·9	40 50 23	v F; R; v S; g b M; 10″; in field with a double star	257
1657	Nova.	13 31 40·3	84 4 4	e F; among stars. Wind extremely troublesome	251
		45·6	3 45	v F; R; among some p B stars. (N.B. The R A of this obs to be preferred.)	250
1658	III. 370	13 32 3·6	60 44 1	p B; has a * 9 m 4′ dist; 45° s p	65
1659	III. 410	13 32 38·6	52 16 7	F; p L; r; has a * near	71
		38·8	16 38	F; S; irreg R; r	72
1660	Nova.	13 32 44·5	14 5 2	e F; S; sky perfectly clear	348
1661	Nova.	13 33 13·4	50 21 6:	p F; R; 20″; has a small * p	155
		13·4	20 21	F; S; R; g b M; 20″	73
		14·6:	21 56:	e F; R; has a * n p dist 3′	335
		14·8	19 56	No description	156
1662	Nova.	13 33 34·7	84 52 35	e F; S; between 2 stars	141
1663	M. 3	13 34 12·2	60 46 22	A most superb object, diam = 10ᵐ·0 of time in R A. Not less than 1000 stars 11 m and under. They run into a blaze at the centre, and form as it were radiating lines and pointed projections from the mass, with many stragglers.	417
		18·0	45 51	I just see the stars through a cloud so thick as almost to obscure Arcturus; 6′ diam, but in a clear night no doubt more.	64
		18·1	46 8	Observed with Capt. SMYTH, who "saw something remarkable" in a small * 2ᵐ or 3ᵐ preceding it, which proved on closer examination to be a fine first class double *.	415
		19·5	45 46	Very beautiful; stars 11....15 m; fills field, making lines and irregular rays of stars, and coming up to a blaze in the middle.	65
		20·7	45 38	A noble globular cluster 5 or 6′ diam, entirely resolved *when not a star near it, even Arcturus, was visible to the naked eye for clouds.*	343
1664	I. 98	13 34 35·5	53 28 42	B; R; first g and then p s b M; 50″	331
		36·3	28 22	p B; R; g m b M; 50″	71
		36·3	28 48	B; R; g m b M	72
1665	II. 798	13 35 15·6	33 28 15	v F; double neb; pos = 73°·0 by microm; a large star follows dist = 15′ ±.	347
		19·3	28 20	v F; l E; s p a bright *	346
1666	II. 668	13 37 52·5	47 38 28	v F; v S; R; almost stellar	151
1667	III. 785	13 38 50·1	33 51 20	e F; hardly more than a violent suspicion, owing to auroral light in the sky.	347

No.	Synonym.	R 1830·0.	N.P.D. 1830·0.	Description and Remarks.	Sweep.
		h m s	° ′ ″		
1668	I. 180	13 39 16·3	45 18 28:	Not v B; E 45° n p to s f by diagram; g b M	151
1669	II. 533	13 39 38·9	85 12 28	v F; v L; l E; v g b M; 2′ l, 3′ br. In the obs the minute of R A comes out 38 instead of 39, but this is an obvious mistake.	143
		39·3:	12 35	v F; v L; R; v g l b M	141
1670	II. 688	13 40 ±	43 0 23	p F; R; m E	255
1671	II. 306	13 40 17·1	96 23 5	e F; R	137
1672	III. 681	13 40 21·8	50 51 15	p B; S; has two nuclei or involves a double star	155
1673	III. 621	13 40 32·4	51 19 7	e F; S; R	331
		33·2	20 39::	e F; a strong haze; P D uncertain	28
1674	I. 255	13 41 19·9	28 9 57	p B; S; m E in pos 57°·4 by micr; p s b M; 30″ l	344
1675	II. 710	13 41 39·5::	49 10 41::	e F; hardly visible for haze. The preceding of two in parallel. (N.B. As haze cleared, p B.)	335
		40·4	10 5	F; v S; R; s b M	73
1676	III. 422	13 42 16·6	55 32 26	v F; R	74
		18·4	32 0	v F; the first of 3; pos with III. 423 = 241°·5 by micrometer	337
1677	Nova.	13 42 26·5::	49 10 41::	The f of 2 in parallel; p B; p L; l E; g b M	335
		29·5	10 42	p B; S; E; l b M; the f of 2	73
1678	Nova.	13 42 37·8	84 9 30	v F; v L; v g b M; R	141
1679	III. 423	13 43 2·4	55 27 5	p B; S; R; p s b M; 15″; the second of 3	337
		...	28 ±	F; S; R	131
1680	Nova.	13 43 8·9	55 30 39	e F; at first sight very like a ✱, but on long attention a p L neb surrounds it. Pos with III. 423 = 159°·5 by microm.	337
		...	30 ±	p B; R; s m b M; taken much past meridian. No R A procured	74
1681	II. 307	13 43 9·7	95 12 16	F; L; R; g b M; 50 or 60″	147
1682	II. 669	13 43 10·9	47 47 14	F; R; g b M; 40″	151
1683	II. 685	13 43 19·4	91 21 34	F; R; a ✱ precedes	146
1684	I. 256	13 43 33·0	28 57 17	v B; R; p s b M; 40″	344
1685	II. 712	13 43 33·8	49 35 14	No description	156
		34·8	35 47	p B; S; l E; s b M; 15″	155
		39·8::	34 28	F; R; p s b M; 30″. Twilight and ☾; a very doubtful R A, and a presumed mistake of wires. If not, is a new neb.	357
1686	III. 549	13 43 33·9	86 49 28	p B; R; p s b M; 15″	143
1687	III. 929	13 43 36·8	87 3 17	A very insignificant cluster of v S scattered stars; or a S resolved neb.	144
		...	5 ±	The faintest thing imaginable; sky turbid. Not found till too late for the transit, and seen with difficulty.	145
1688	Nova.	13 44 18·6	86 20 1	F; irreg R	142
1689	II. 899	13 44 25·8	12 19 22	e F; R; 15″; sky perfectly clear	348
1690	II. 670	13 45 5·4	45 54 54	v F; R; p s b M; 30″	151
1691	III. 698	13 45 9·2	49 28 40:	S; irreg R; has a B ✱ 8 m, p	155
1692	II. 308	13 45 16·1	96 45 15	v F; S; R; b M. Dull and murky sky	137
1693	II. 686	13 45 29·9	90 35 42	p B; S; R; g b M; 15″	146
1694	III. 849	13 45 43·6	29 16 59	e F. Sky nearly perfect	344

No.	Synonym.	R 1830·0.	N.P.D. 1830·0.	Description and Remarks.	Sweep.
		h m s	° ′ ″		
1695	II. 424?	13 45 47·1	55 40 36	p B; L; R; 40″. If this be my Father's nebula, there is an error of 6′ in his P D.	74
1696	II. 713	13 46 7·3	48 48 34	p B; R; b M	156
		11·0	46 17:	v F; L; a bright D * p; the first of 4	357
		14·3::	49 ±	Place extremely vague	155
1697	II. 697	13 46 8·6	51 15 7	p B; L; 1 E in parallel; v g b M; 90″ l	331
		8·8	14 29	v F; L; R; 1 b M; 2′	73
1698	II. 714	13 46 10·8:	48 53 29	The southern of a double neb, dist 1′ in meridian	156
		18·5::	51 ±	p B; S; the southern of 2 nearly in meridian; the second of a group of 4. Place very loosely taken.	357
		20·3:	57 ±	Place very loose, and P D especially so from fluctuating zero	155
1699	II. 715	13 46 10·8:	48 52 29	The northern of a D neb, dist 1′ in merid	156
		19·5::	50 ±	F; S; the northern and smallest of 2 in merid; one of a group of 4	357
		20·3:	56 ±	Place very loose, and P D especially so	155
1700	II. 415	13 46 13·4	53 1 12	p F; R; 30″; has a * 90″ dist, 25° n f	71
		14·1	1 8	F; R; 1 b M	72
1701	III. 506	13 46 24·8	83 49 36	e F, but the sky very dull	142
		25·4	50 3	e F; E	143
		26·0	49 37	p F; L; m E; r; 80″ l, 30″ br	253
		26·3	49 29	F; R; has two stars n and n f	154
		27·0	49 7	F; E; g b M; by diagram it is a narrow ray, pos 75° n f to s p	153
1702	Nova.	13 46 26·3::	48 49 ±	The last of a group of 4	155
		31·3	49 54	F; the last of 4. There is a * 9 m preceding the group	156
		...	47 ±	v F; L; the last of 4. P D very rough	357
1703	I. 6	13 47 33·1	83 54 41	p B; R; p s b M; sky not clear	142
		34·6	54 38	v B; R; p s b M; 30″	143
		36·2	54 59	B; R; p s b M; a * 8 m n f; 4′ dist	427
		36·3	54 16	p B; S; R; s b M; 25″	152
1704	III. 285	13 47 59·5::	94 39 36::	v F; v S; R. Observed too late; place precarious	147
1705	II. 534	13 48 2±	84 10 ±	v F; R; p L; g b M; 50″. R A not observed, but set down from working list.	143
		...	8 54	F; v L; R; v g b M; 2′	427
1706	III. 786	13 48 15·5	34 49 45	p F; S; R; g b M; 15″	347
		21·0	49 40	e F; R; s p a * 16 m; sky nearly pure	346
1707	II. 716	13 48 30·9	48 40 47	No description	357
1708	II. 843	13 48 40·3	28 28 38	No description	344
1709	III. 809	13 48 47·7	30 30 42	Not v F; S; E. I almost suspect it to be a double * 13 and 14 m involved in nebula.	345
1710	II. 889	13 48 55·2	83 4 12	p B; R; v g l b M; has a * 11 m, 5° n p	253
		59·4	3 47	F; S; 1 E; v g b M; follows a * 4 sec	154
		59·8	4 4	F; L; R; follows a * 12 m (whose dist from edge of neb = 1 radius by diagram).	251
		61·6	4 12	v F; R; has a * 11 m p, 70″ dist	250

No.	Synonym.	R 1830·0. h m s	N.P.D. 1830·0. ° ′ ″	Description and Remarks.	Sweep.
1711	III. 125	13 49 12·5 :	59 61 2	pB; R; g b M; 45″. No other near in the parallel, following	417
		16·1	59 46	pB; p L; R; g b M; 40″. No other in the parallel before or after, for some distance.	342
		17·3	59 36 :	Not v F; R; p s l b M; 20″. If this be III. 125, my Father's place is much out in R A.	258
1712	I. 187	13 49 25·2	41 56 32	B; v m E; v s m b M	256
		29·5	55 1	B; L; m E; s m b M to nucleus	257
		29·5	56 28	p B; m E (40° n f to s p, by diagram,); s b m to nucleus	140
		34·1	56 19	v B; m E; p s b M; 50″ l, 15″ br; pos = 40°·4 by microm	255
1713	Nova.	13 49 30·1	51 22 42	p B; l E; v g l b M	331
1714	II. 698	13 49 38·1	51 33 37	p B; R; p s b M; 40″	331
		38·8	33 54	v F; S; R; r	28
		40·7	32 48	F; R	73
1715	III. 546	13 49 45·7	82 54 42	Like a * 15 m rubbed out	153
		...	55 ±	A nebula like a hairy star	250
1716	III. 547	13 49 52·7	82 49 32	A neb like a double * obliterated; pos by diam = 55° or 60°	153
		...	50 ±	Like a hairy star	250
1717	I. 181	13 50 3·0	47 19 28	Not v B; R; g b M; 40″	151
1718	Nova.	13 50 15·4 :	48 43 46 :	F; L; v g b M; has a * 9 m, n f, 4′ dist	335
1719	I. 240	13 50 31·0	29 24 36	v F; sky not perfectly clear	344
1720	III. 666	13 50 37·9	92 22 32	F; S; R; g b M; 20″	146
1721	Nova.	13 51 6·8	12 59 7	A cluster of 11 stars 11 m, and 2 of 15 m	348
1722	I. 191	13 51 17·4 :	51 44 ±	The smaller and n p of 2 which nearly join, constituting a double nebula. The place merely estimated by diag from I. 190.	331
		17·7	42 28	v F; S; the n p of 2 very near	73
1723	I. 190	13 51 20·2	51 45 9	F; b M; E nearly in merid	28
		20·4	45 47	The larger and s f of 2 which nearly join	331
		22·2	44 13	F; E; l b M; by diag. The pos of the longer axis is about 60° n p and points towards I. 191, which it almost joins.	73
1724	III. 411	13 52 4·0	54 24 17	v F; v S; p m E in parallel	131
		8·1	23 22	e F; v S	71
1725	III. 412	13 52 22·0	52 55 18	F; S; E; b M	72
1726	III. 683	13 52 35·2	50 59 13	e F; p L	155
		46·1 : :	59 12	No descrip. R A hurriedly taken by comparison with a star in parallel and not to be depended on.	331
1727	III. 810	13 52 43·6	29 19 50	e F; e S	344
1728	II. 699	13 53 7·4	50 14 57	No description	357
		8·8	15 34	v F; S; R; b M	156
1729	II. 672	13 53 45·1	48 10 50	No description	156
1730	III. 11	13 53 47·3	81 8 4	v F; S; R; p s b M	154
		47·6	9 7	Not v F; S; R; p s b M; 12...15″	153
		48·4	8 7	F; R; g b M. Follows several stars	251
		49·3	8 27	p F; R; p s b M	250

No.	Synonym.	Æ 1830·0. h m s	N.P.D. 1830·0. ° ′ ″	Description and Remarks.	Sweep.
1731	Nova.	13 53 50·7	81 29 37	vF; R; bM; well seen	253
1732	III. 684	13 53 58±	50 0 31	vF; vS; R; bM; among a cl of st 10 m. R A by working list	73
1733	Nova.	13 54 21·1	24 15 46	pF; pS; R; psl bM; 20″; has a * 7·8 m; Δ R A = 37ˢ; Δ P D = 60″ ±.	411
1734	II. 309	13 54 25·7	95 9 52	The first of 2. Both L; F; vg bM; R; r; 3′ dist; 70° np. The larger taken.	147
1735	II. 310	13 54 29·7	95 12 41	The second and larger of 2	147
1736	I. 230	13 54 38·6	34 0 30	pB; mE; vsbM; 50″ l	347
		43·3	0 40	pB; S; pmE; psbM	346
1737	III. 653	13 55 6·8	56 40 17	vF; S; E in merid	131
		8·0	40 26	F; S; R; bM; 20″	74
1738	II. 827	13 55 15·7	29 49 50	pF; R	344
1739	II. 416	13 55 39·5	54 24 48	F; S; R; bM; has a * 11 m sp 1′ dist	72
1740	Nova.	13 56 ±	54 31 57	Taken for II. 416, which it cannot be if the last obs be correct. vF; S.	131
1741	II. 417	13 56 0·7	54 3 15	pB; R; sbM; 15″	337
		1·8	2 39	p B; R; vsmbM almost to a *	28
		3·0	2 27	B; R	71
1742	III. 413	13 56 7·7	54 9 50	pF; near a * 13 m sp	337
1743	II. 691	13 56 21·8	40 0 33	pB; L; vmE; psmbM; 4′ l, 20″ br; a ray with a nucleus	257
1744	M. 101	13 57 9·1	34 48 40	F; vL; R; first g then vsmbM; 5′	347
1745	III. 286	13 57 40·2	94 38 16	vF; vL; R; gbM	147
1746	VI. 9	13 57 46·4	60 39 44	a L, v rich cl; 8′ .... 10′ diam; stars 12 .... 18 m; roundish figure.	417
		49·0	39 16	Fine L cl; stars 14 m downwards to a nebulous appearance; 6′ ... 8′ diam. It will bear no illumination.	65
		...	.....	Viewed; a fine L cl 7 or 8′; vgbM, but no nucleus. The stars 11 or 12 m down to an irresolvable mass; irreg R; excessively compressed. A fine object. Barely discernible in the 20 feet finder (2½′ in aperture).	357
1747	III. 947	13 57 51·1	10 57 7	eF; pL; R; vgvlbM; 35″. R A precarious, owing to a great extra meridian correction.	348
1748	I. 231	13 58 47·8	34 17 10	pF; R; S; gbM; sky not quite clear	346
1749	Nova.	13 59 4·8	83 8 47	F; mE; vglbM	250
1750	II. 800	13 59 18·9	33 26 45	pB; S; pmE; bM; 18″ l, 12″ br	347
1751	III. 287	13 59 21±	95 17 ±	F; pL; R. R A by working list. P D roughly taken, past merid	147
1752	II. 32	14 1 52·0	71 38 26	pB; vS; has a vF double * in centre among several stars 12 m; a doubtful object.	334
		...	39 ±	vF; S; R; sbM	61
1753	II. 890	14 2 29·3	82 49 40	pF; pL; gbM; 25″	154
		30·0	49 37	pF; S; R	253
		30·7	49 31	No description	250
		...	52 ±	pB; bM; r. Viewed much past merid, and P D extremely vague.	153

No.	Synonym.	R 1830·0.	N.P.D. 1830·0.	Description and Remarks.	Sweep.
		h m s	° ′ ″		
1754	II. 876	14 2 37·3	69 35 11	pB; vS; E	61
		...	36 ±	PD taken past meridian	334
1755	IV. 46	14 2 38·4	94 14 16	pB; R; psmbM; 15″; seems to have * 18 m involved n p.	147
1756	Nova.	14 3 41·8	87 56 32	avF neb or avS cluster of e S st	144
1757	II. 687	14 4 25·9	92 24 12	vF; L; 1E; gbM	146
1758	IV. 49	14 4 32·7	92 20 57	F; S; R; bM	146
1759	II. 877	14 5 12·4	68 46 10	pB; R	409
1760	III. 685	14 5 36·6	49 53 20	F; S; 1E; 15″	73
		36·8	53 5	No description	357
		37·0	53 44	F; irreg fig; seems to have a * in it	155
1761	Nova.	14 6 50·4	84 47 36	F; S; R; bM; 15″	143
1762	III. 134	14 7 5·9	63 53 17	eF; pL; a * 10 m 150″ dist np	261
		8·7	53 10	pB; pL; mE; 2′ l, 30″ br	425
		13±	53 55±	pB; mE; 60″ l, 20″ br; a * 10 m p	350
1763	III. 804	14 8 20·5	31 25 57	eF. Moon rising, but no doubt	345
1764	III. 414	14 8 24·1	52 59 7	pF; vmE; a long narrow ray pos = 110°·3 by microm; vgvlbM; 90″ l, 12″ br.	331
1765	III. 47	14 8 34·3::	78 23 52	F; R; gbM	4
1766	II. 418	14 8 58·4	53 52 40	pB; R; psbM	337
		53·8	49 59	R; vsmbM to 2 or 3 stars	28
		54·3	51 37	No description. (An extraordinary disagreement in P D, yet none of the observations is marked as defective.)	71
1767	Nova.	14 9 14·7	81 1 47	F; irreg fig; pL; gbM; r	253
1768	III. 731	14 9 26·4	49 43 9	F; R; the p of 2, or perhaps of 3	156
1769	III. 732	14 9 34·1	49 36 56	pF; S; R; gbM; 10″	357
		34·3	37 9	pB; R; perhaps a third neb near	156
		35·5	37 15	F; S; R; 15″	73
		...	37 45::	vF; vS; R; sky perfectly clear	155
1770	III. 551	14 9 44·5	81 38 30	pB; R; bM; 20″	154
		45·2	38 33	pB; R; gbM; 20″	250
1771	II. 419	14 9 52·4	52 38 15	E	69
		53·3	37 38	F; S; a double nebula or two which run together pos 10° n f by diagram.	72
		...	38 57	F; E	71
1772	III. 552	14 10 14·5	81 50 17	F; R; bM; 20″; only one seen with much attention. Sky perfectly clear.	153
1773	II. 194	14 10 16·0	64 4 10	vF; pL; R; vsvmbM, to a * 12 m, for which it is easily taken.	261
		17·1	4 20	B; vsvmbM; like a * with feeble atmosphere	425
1774	Nova.	14 10 16·9	76 19 29	vF; pmE; 30″ l, 15″ br. Just comes into the field with 18 Bootis.	338
1775	Nova.	14 10 51·9::	62 56 27::	vF; 1E; 15″	350

No.	Synonym.	R 1830·0.	N.P.D. 1830·0.	Description and Remarks.	Sweep.
		h m s	° ′ ″		
1776	I. 99	14 11 17·0	52 42 34	B; R; v s m b M to a *; v F at the borders	28
		17·0	43 5	v B; R; m b M	69
1777	III. 347	14 11 29·1	64 24 20	v F; R; b M	425
1778	II. 579	14 11 29·5	85 12 41	p B; p L; l E; g b M.	142
		31·7	13 9	v F; L; g l b M; 90″.	427
1779	I. 144	14 11 45·3	85 17 7	B; R; 40″; g b M; r; has a * 12 m l diam of neb (by diagram) dist, n f.	426
		46·0	16 31	v B; p L; R; s b M	142
		47·0	16 39	B; R; p s b M; 18″	427
1780	Nova.	14 12 4·6	54 5 35	p F; R	337
1781	III. 12	14 12 14±	81 42 ±	Not v F; S; R; b M. (R A by working list.)	153
		...	42 ±	Seen; as also III. 551 in the same parallel, but considerably dist in R A.	251
1782	I. 145	14 12 21·4	85 58 33	F; S; l E	143
1783	I. 146	14 12 30·4	85 56 48	v B; R; v s m b M; a star 11 m n p and the neb I. 145 s p make a right-angled triangle with I. 146 at the right angle.	143
1784	III. 415	14 13 14·1	54 1 47	e F; L; 30 or 40″	331
		16·7	1 8	F; p L; the preceding of 2	72
1785	Nova.	14 13 29·3	54 0 33	Not v F; 20″; the following of 2	72
1786	II. 754	14 13 48·2	49 30 51	B; R; p s m b M; 20″	357
		49·0	31 23	F; R; b M.	155
		49·4	31 14	p B; S; R; s b M; 10″.	156
		...	33 ±	p B; R; g b M; 30″; has a * 11 m 50° s p, dist 80″. No R A procured, and P D only rough.	73
1787	III. 110	14 14 3·9	75 18 20	v F; R; g b M. Is n p a * 8 m 6′ dist.	338
1788	III. 416	14 14 14·5	53 57 14	The n p of 2. Pos with the other = 330°·0 by micrometer.	337
		15·2	56 37	v F; S; R	71
1789	Nova.	14 14 14·7	54 5 39 :	e F	28
1790	I. 235	14 14 20·8	32 29 47	v F; v L; R; v g b M; diam 2′ at least; ☾ and haze.	345
1791	III. 417	14 14 26·0	54 1 20	p B; R; p s b M; 15″; the s f of 2; ☾	337
		27·7	0 39	v F; a stellar nucleus.	28
		28·2	0 57	p F; R; 20″	71
1792	III. 121	14 14 53·8	105 56 58	F; v L; R; v g b M; 2′ diam	354
		...	56 43	F; L; R; v g l b M; 60 or 80″ diam; the first of 2; Δ R A = 15ˢ.	157
1793	III. 122	14 15 7·8	105 59 13	v F; L; l E; v g l b M; 90″	354
		...	59 23	v F; L; R; the second of 2; 60 or 80″ diam; Δ R A = 15″.	157
1794	III. 927	14 15 23·8	82 38 32	v F; E; g b M	253
		24·3	38 31	v F; R; b M; 12″	154
		24·7	38 55	p F; S; R	250
		25·5	38 17	No description	153
1795	III. 418	14 15 26·6	52 6 7	e F; S; R; (unless R A = 14° 15ᵐ 36ˢ·6)	331

No.	Synonym.	Æ 1830·0.	N.P.D. 1830·0.	Description and Remarks.	Sweep.
		h m s	° ′ ″		
1796	III. 733	14 15 32·3:	48 51 16::	The places of this sweep are bad	155
		37·1	54 14:	F; R; b M; 12″...15″	156
1797	II. 177	14 15 41·8	74 35 7	p B; R; g b M; 40″	24
1798	III. 120	14 15 53·6	102 24 12	v F	351
1799	III. 688	14 15 54·9	92 25 57	F; p L; v g b M to a stellar point	146
1800	III. 734	14 16 11·0	48 51 14::	p B; R; b M; 15″	156
		13·1	49 44	v F; R; g b M; 12″	357
1801	III. 673	14 16 36·7	47 26 58	F; R; p L; v g b M; 80″. Sky very fine	151
1802	III. 136	14 16 42·2	64 37 5	p F; p m E; g b M; 30″; a * 9 m follows 20ˢ in the parallel.	425
		...	37 35	v F; R; p g b M; 20″	261
1803	Nova.	14 16 49·3	56 10 46	F; S; R; v s m b M	74
1804	II. 420	14 16 54·2::	54 21 47::	p B; R; 30″	71
		58·8	21 38	p B; R; s b M; 30″	72
1805	III. 419	14 17 16·4	52 45 52	v F; S; 1 E; v g b M	331
1806	Nova.	14 18 45·9	84 25 43	v F; R; v g b M; 25″	143
1807	III. 14	14 19 26·2	80 59 16	The faintest possible	250
1808	II. 329	14 19 55·9	55 59 1	F; S; R; v s m b M; 15...20″; almost stellar	74
1809	III. 677	14 19 58·6	40 40 37	v F; p L; R; v g l b M; 30″	257
1810	Nova.	14 20 13·4	49 16 48	v F; S; R; g b M; 20″	73
1811	Nova.	14 20 20·4	77 51 2	v F; R; 15″; about 3′ f, and 40″ n of a * 9 m	338
1812	Nova.	14 20 37·4	63 23 30:	p F; R; g b M; 20″. Precedes Piazzi xiv. 97	350
		40·7	23 15	p F; R; has a * 7 m f	425
1813	I. 70	14 20 40·5	95 12 19	A fine small compressed globular cluster. I can barely discern the stars; they are 19 m 80″ diam; has a * 7.8 m 90″ dist, pos 30° s f, and another 10 m, n p.	147
1814	II. 674?	14 20 52·0	47 58 14:	No description	156
		52·5	58 38	F; E in parallel; 45″ l, 30″ br	151
		53·5	58 57	e F; S; R; sky perfectly clear	150
		54·0	58 58:	F; p L; g b M; 35″	155
1815	III. 132	14 21 1·1	61 49 51	p B; S; E; s b M	65
1816	II. 580	14 21 4·0	85 57 51	e F; R; the n p of 2	142
1817	II. 581	14 21 6·0	85 59 51	v B; R; p s b M; 15....20″	142
		6·4	60 23	p B; R; p s b M; 15....20″	143
1818	I. 185	14 21 6·6	43 4 49	B; R; v g l b M; 40″	255
		7·1	5 22	Not v F; R; v g v l b M; 20″	256
1819	II. 357	14 21 11·0	66 3 0	e F; v S; R	425
		16·8	2 55	e F; R; v g b M; 15″	261
1820	I. 236	14 21 14·1	32 39 37	B; R; p s b M; 30″	345
		14·3	39 40	B; R; p s b M; 25″	347
1821	Nova.	14 21 23·3:	58 50 12	v F; R; n of a * 11 m; a * 7.8 m precedes	258
1822	III. 126	14 21 51·0	59 12 57	p B; v S; close to and n p a * 12 m; pos from * = 333°·5 by microm	342
		55·4::	14 1	F; S; has a * in it and a B * foll it	65

No.	Synonym.	R 1830·0.	N.P.D. 1830·0.	Description and Remarks.	Sweep.
		h m s	° ′ ″		
1823	II. 150	14 22 14·4	81 57 53	v F; L; R; 60″	152
		15·4	57 49	p B; R; g b M. Wind very troublesome	251
1824	III. 645	14 22 28·1	75 14 13	The faintest perceivable; the first and northern of 2	338
1825	II. 891	14 22 33·9	83 15 27	p B; p L	253
		35·2	15 54	p B; p L; R; b M	153
1826	II. 330	14 22 50·3	58 1 38	F; S; R; b M; 25″	74
1827	Nova.	14 22 51·5:	75 19 52:	The s f of 2; the faintest perceivable	338
1828	III. 420	14 23 0·6	52 52 42	p F; nucleus elongated, or has a F double * in it. Pos = 115°·5 ± (microm).	331
1829	II. 421	14 23 18·5	53 55 20	(II. 421, *not* III. 421.) p B; R; p s b M; 20″; a * 9 m follows 18ˢ·5 nearly in parallel, and a * 14 m, pos 155°·0 from neb, dist 50″.	337
		18·9	55 0	B; R; m b M; a star near or in it	69
		21·2	54 9	F; R; r	28
		...	55 12	Seen. No description. Working list much out in P D	71
1830	II. 892	14 23 30·4	82 59 57	v F; p L; irr fig	250
		30·8	59 5	v F (growing hazy)	154
1831	III. 289	14 23 32·1::	63 51 5::	e F. Place extremely precarious	261
		...	.....	Viewed; v F; R; v g b M. In or near its place per working list.	425
1832	II. 695	14 23 49·6	39 37 45	p F; v L; R; v g b M; 2′; r; stars = 20 m	257
1833	II. 27	14 24 3·0	81 10 27	p B; R; g b M; 30″	153
		3·1	9 57	p B; L; g b M; 90″	253
1834	Nova.	14 24 52·2	78 43 32	v F; R; 10″. Stellar; hardly distinguishable from a star	4
1835	Nova.	14 24 52·8	84 47 46	v F; p L; R; has a * 15 m, n f, involved or very near	142
		52·9	48 0	F; p L; R; has * 13 m, n f involved	143
1836	III. 310	14 25 22·7	57 34 41	v F; R; l b M	74
		...	36 ±	Viewed. It is pointed to by a D * preceding	258
1837	II. 893	14 25 23·2	83 47 2	F; R; g b M	253
		23·8	47 7	p B; p L; g b M	250
		24·0	46 59	v F; R; b M; 20″	251
		24·8	46 55	v F; R; b M; growing hazy	154
1838	II. 696	14 25 39·1	39 18 13	v F; p m E; s f a star 15 m	257
1839	II. 422	14 25 39·5	52 56 35	F; S; E; b M	72
1840	III. 289	14 26 34·9::	63 46 57	F; R; r; has 3 stars 9.10 m n p	350
1841	II. 894	14 26 37·1	83 52 39	e F. Third class. Windy, but sky very clear	251
		41·0	53 17	Just following a *. Cloud renders the observation doubtful. (N.B. The obs makes the P D 81°, but it is pretty evident that there is a mistake of 2° in reading the index, and that this belongs to II. 894.)	153
		...	53 7	v F; b M; some doubt if it be a nebula	253
		...	53 17	Among stars and seems attached to a * 12 m like a wisp	250
		...	55 33	e F; S; R. Taken beyond meridian, and probably a hurried observation.	143

No.	Synonym.	Æ 1830·0. h m s	N.P.D. 1830·0. ° ′ ″	Description and Remarks.	Sweep.
1842	I. 189	14 26 48·0	39 47 15	B; L; E; r; p g m b M	257
1843	I. 237	14 26 58·5	31 19 44	B; 1E in merid; g m b M; 50″	345
		71·1::	21 13:	B; L; R; v g b M; 40″. Noted in the MS. as a hasty observation, and with a doubtful R A caught in quitting the field.	225
1844	III. 421	14 28 51·5	52 42 48	F; S; R; b M	72
		52·6	41 59	F; R or 1E	28
		53·1	44 2	p B; R. The preceding of 2	331
		54·6	43 17	v F; E	71
1845	Nova.	14 29 5·1	52 45 12	v F; S; R	331
		5·5	45 3	v F; v S. The following of 2	72
1846	III. 582	14 29 8·7	86 57 51	e F; E; about 10ˢ following a * 7 m	142
		...	58 12	F; seems to be a double nebula (pos by diagram = 140° ±) foll a * 6 m.	426
		...	58 34	a v F ray 60″ l; follows a * 7 m dist 5′	427
1847	II. 681	14 29 10·4	89 38 52	p B; g b M; 1E	144
1848	I. 188	14 29 26·2	40 30 48	B; S; p m E; p s b M; pos nearly in the parallel	257
1849	II. 808	14 29 29·7	34 46 0	F; irreg fig; r; has * 10 m, 2′ s f	347
1850	II. 648	14 29 59±	47 28 7:	F; R; r. R A by working list	150
1851	II. 423	14 30 23·9	52 41 25	p B; S; b M	69
		25·4	41 38	p B; R; b M	72
		...	41 57	p F; R	71
1852	II. 700	14 30 26·4	50 47 56	F; S; irreg fig; b M	73
		27·2	47 49	No description	156
		...	48 27	F; p L; 1E; 40″ l; in a scalene triangle of stars 10.11 m	331
1853	II. 675	14 30 29±	47 38±	v F; R; b M; follows an arc of 4 B st	151
1854	II. 575	14 30 41·9	83 53 51	B; R; p s b M; 30″	143
		43·0	53 27	p B; S; R; g b M; 25″	253
		43·8	53 32	p B; p s b M; 30″	152
		44·3	53 13	B; p S; R; b M; has * 11 m 15ˢ prec	154
1855	II. 649	14 31 16·1	48 44 41	F; S; R	155
		36·4	47 33::	v F; p L; R; scarcely visible, for ☾. (N.B. The great difference of R A from that of the 155th sweep is probably owing to mistaking the moveable micrometer wire for the fixed wire of the eye-piece.—The P D of this obs is also evidently faulty.)	357
1856	III. 895	14 31 27·4	69 13 11	e F; S; v g b M; the p of 2; a double * between	334
1857	I. 182	14 31 27·9	89 32 52	B; R; p s b M; r; 20″	144
1858	Nova.	14 31 32·9	69 17 1	e F; v S; the f of 2, close to a D *	334
1859	Nova.	14 31 34·8	48 49 14:	No description	156
		36·6	48 42:	F; p L; E nearly in merid; g b M	155
1860	III. 671	14 31 38·8	106 44 29	e F; L; R; 60″	354
		39·5	43 53	v F; p L; very ill defined	157

No.	Synonym.	AR 1830·0.	N.P.D. 1830·0.	Description and Remarks.	Sweep.
		h m s	° ′ ″		
1861	Nova.	14 31 57·5	42 36 39	vF; E; 40″ l; S of a coarse D *; the preceding of 2	255
1862	III. 550	14 32 9·2	85 48 33	vF; R; vglbM; has a * 9 m 45° nf	143
		...	47 52	vF; spa * 8 m, 1½ diam from edge of nebula	426
1863	II. 682	14 32 12·8	89 34 35	pB; S; 1E; bM	144
1864	III. 675	14 32 20·4	42 35 ±	The second of 3 in a line (two R; one m E) south of a double *. P D from Sw 255.	256
		27·5	34 39	Not e F; R; psbM; 20″; the second of 3	255
1865	Nova.	14 32 44·5	42 33 9	vF; R; psbM; 15″; the third of 3 in a line	255
1866	I. 184	14 32 58·3	106 31 5	F; R; pgbM; 20″; has a * 15 m nf; certainly not of first and hardly of second class. Sky perfectly clear.	354
		58·3	30 26	pB; mE; bM, almost to nucleus; has a * 10 m 90° s	157
1867	III. 657	14 33 33·5::	46 28 23::	eF; pL; E; seen only with great attention. Place estimated from III. 658.	151
1868	III. 658	14 33 43·5	46 29 53	vF; S; R	151
1869	III. 686	14 33 48·4	50 37 14	No description	156
		54·1	37 36	vF; S; R; bM	73
1870	III. 133?	14 35 11·2	60 33 1	vF; L; R	65
1871	III. 896	14 35 19·6	70 23 21	vF; pS; R; glbM	334
1872	II. 538	14 35 46·4	87 35 32	L; irreg R; gbM; r	144
1873	I. 171	14 36 3·7	47 26 42	pB; R; sbM; several small stars near	150
1874	I. 126	14 36 17·6	87 19 17	A long p B ray with a p B nucleus; 3′ long	144
1875	I. 188	14 37 37±	89 31 ±	F; R; gbM; r; 30″; is not entitled to be called first class. Sky perfectly clear.	144
1876	III. 690	14 38 13·3	108 22 6	F; S; R; bM	355
1877	II. 809	14 38 27·5	35 51 25	vF; R forms an obtuse-angled isosceles triangle with 2 = stars 10.11 m, one p, one sf; dist of each 3′.	347
1878	III. 687	14 38 35·4	50 32 57	eF; just visible. ☾	357
		36·7	32 58	pB; R; psbM; 15″	155
		37·5	32 5	F; S; R; gbM; 20″	73
1879	III. 885	14 39 50·0	70 46 56	vF; 1E in parallel; vglbM	334
1880	Nova.	14 42 22·7	84 10 27	vF; a double nebula, both individuals eF	253
1881	II. 576	14 44 43·2	85 20 21	pB; R; sbM; 25″	143
		...	19 46:	No description. R A lost	142
		...	20 14:	F; S; R; gbM; 15″	427
1882	III. 129	14 45 0·3	59 27 35	vF; S; R; pgbM; 15″	258
1883	Nova.	14 45 7·2	48 42 4	B; R; sbM; 15″	156
		7·9	42 14:	pB; pL; R; gbM; 20″; a * 8 m, np	155
		10·7	40 42	pF; 1E; pslbM; 20″	357
1884	III. 130	14 45 17·8	59 30 25	vF; R; pgbM; 20″	258
1885	III. 554	14 45 28·6	85 46 18	Not vF; gvlbM; a narrow ray, 90″ l, 15″ br	143
		...	45 4	Not vF; mE; pos = 140°·0 ±; 90″ l	427
		...	45 37	vF; vmE; a ray, pos = 148°·4 by microm; 90″ l	426

No.	Synonym.	R 1830·0. h m s	N.P.D. 1830·0. ° ′ ″	Description and Remarks.	Sweep.
1886	Nova.	14 47 11·9	106 32 41	F; S; R; b M; has a * 16 m s p near	354
1887	II. 676	14 47 58·5	46 45 22	S; R; almost stellar; s b M; 15″	150
		59·2	45 8	p B; R; s m b M; 20″	151
1888	II. 677	14 48 55·6	46 48 42	S; R; p s b M; 12″; like a burred star	150
1889	III. 691	14 49 10·2	108 35 7	p F; R; b M; 20″	355
1890	III. 976	14 49 25·1	59 5 34	e F; p L; 40 . . . . 50″	65
1891	Nova.	14 50 22·1	39 37 22:	p F; S; v s b m, to a * 13 m; the first of 3 in a line. A star 6.7 m near.	257
1892	III. 131	14 50 32·3:	59 21 8:	v F; R; v g l b M; 20″; has a * n f	258
		. . .	20 48	e F	65
1893	III. 679	14 50 47·1	39 37 36	p F; S; v s b M to a * 13 m; the second of 3 in a line. A star 6.7 m near.	257
1894	II. 539	14 51 22·9	87 25 32	B; s b M to nucleus; E pos 75° n p	144
1895	III. 678	14 51 31·9	39 38 1	p F; S; v s b M to a * 13 m. The third of 3 in a line; a * 6.7 m near.	257
1896	I. 127	14 52 34·3	87 37 2	B; R; p s b M; 40″	144
1897	Nova.	14 52 44·3	87 42 32	v F; v S; R	144
1898	II. 756	14 53 36·5	35 24 50	B; R; s b M; precedes a splendid D *	347
1899	II. 539	14 55 40±	88 7 32:	No description. R A by working list	144
1900	Nova?	14 55 56·6	122 27 28	A very strongly suspected nebula; but I cannot be quite sure (from the low situation) it is not a star.	353
1901	I. 128	14 57 52·4	87 43 37	B; R; p s b M to nucleus; 30″	144
1902	II. 543	14 58 31·4	87 47 44	p F; S; l E; p s b M	144
1903	II. 544	14 59 12·2	86 46 12	p B; R; p s l b M; among many stars	426
		13·7	46 19	p B; S; R; g l b M; 12″; among stars	427
		14·4	46 23	B; S; l E; p g b M	143
1904	IV. 71	14 59 52±	70 53 59::	A star of fully 6 m, with a supposed nebulous appearance about it, but of whose reality I cannot satisfy myself, as it "blinks" with the star behind the wire.	334
1905	II. 751 II. 752	15 0 0±	69 48 ±	A double nebula; pos of the individuals, centre from centre, 20° n p; 2′ dist. Both E; R A from working list; rough P D. (See fig 77.)	61
1906	Nova.	15 0 23·3	46 42 17	F; R; g b M; 20″	150
		24·4	46 43 21	Not v F; S; R; p s b M; 15″	151
1907	II. 585	15 0 58·3	86 17 12	p B; p L; R; g b M	426
		60·7	17 19	p B; irreg R; g b M; 30″	427
		62·2	17 33	p B; S; E; has a * 14 m closely f	143
1908	II. 545	15 1 9·3	88 52 27	p B; S; E; p s b M	144
1909	I. 219	15 1 47·1	33 34 40	v B; p m E; g b M; 50″ l, 20″ br; pos 326°·0 by microm.	347
1910	II. 757	15 5 23·0	32 20 38	B; irr R with ray-like appendages; g b M; r; 30″	225
1911	Nova.	15 6 32·4	48 8 9	F; R; b M; 12″	156
1912	II. 659	15 6 52·7	48 6 8	p B; R; b M; 15″; the P D differs 5′ from my Father's.	156
1913	II. 678	15 7 24·5	47 24 27	F; R; g b M; 30″	150

Fig. 77.

No.	Synonym.	N.P.D. 1830·0.	Æ 1830·0.	Description and Remarks.	Sweep.
		h m s	° ′ ″		
1914	II. 650	15 8 55·4	47 19 58	pB; pmE; psbM	151
		55·8	19 22	vB; pL; pmE; gbM; r	150
1915	III. 660	15 8 55·8	47 10 ±	F; R; gbM	150
		60·3	10 8	vF; lE; bM; small	151
1916	M. 5	15 9 56·4	87 16 27	A most magnificent, excessively compressed cluster of a globular character. Stars 11 ... 15 m; diam in R A = 10 sec of time; the more condensed part projected on a loose irregular ground of stars. The condensation is progressive up to the centre, where the stars run together into a blaze, or like a snowball; the scattered stars occupy nearly the whole field. The neighbourhood is poor in stars. (See fig 87.)	144
1917	II. 759	15 11 24·0	33 4 28	pB; gbM; a ray 6′ or 8′ long at least; pos = 155°·0 by microm	225
		26·2	2 20	B; a superb ray nebula, at least 7½′ long, and narrow; pos = 159°·9 by meas; at first vgb, then psmbM.	347
1918	III. 374	15 12 5·4	91 57 22	vF; R; bM	146
1919	I. 148	15 13 28·9	84 19 13	B; R; psbM; diffused at borders; many stars near	143
		29·6	18 12	pB; E; psbM; 90″ l, 40″ br; among many stars 11, 12, 13 m	253
		30·7	19 37	B; R; vsbM to a * 12 m; among stars	427
		33·3	18 56	pB; ill defined, roundish fig; gbM; among several stars	152
1920	Nova.	15 13 35·4	43 29 44	pB; pmE; vglbM; 60″ l, 40″ br	255
		36·8	30 29	vF; L; mE; vlbM; n of a D *	256
1921	Nova.	15 15 7·5	47 39 42	vF; R; vgbM; 40″	150
		7·8	39 19	No description	156
		8·3	40 39	eF; L; R; 60″	357
		10·3	40 8	F; pL; lE; vgbM	151
1922	III. 661	15 15 43±	47 44 ±	No descr. R A by working list; P D rough	151
1923	III. 874	15 18 18·9	71 19 7	pB; S; R; psbM; a * 7.8 m, 6′ n	334
1924	II. 651. 1	15 20 1·5	47 44 4	The sp of 2 very near constituting a double neb. The fainter and smaller.	156
1925	II. 651. 2	15 20 2·5	47 43 59	The nf, larger and brighter of the double neb. Pos of the other 35° sp, dist about 15″. Not described as double by my Father.	156
		3·5	43 57	pB; bM; R; has a * excentric	150
		5·6	43 28	Not vF; S; bicentral; pos 45° sp ±	357
		6·4	44 3	F; R; bM; 30″	151
1926	II. 401	15 21 55·4	92 14 25	pB; irreg fig; vgbM; 40″	246
1927	II. 178 } II. 179 }	15 26 38·9	74 14 42 {	A fine S double nebula; the individuals are F; R; sbM; r; dist = 1′. Both alike.	24
1928	II. 96	15 28 44·4	72 49 32	F; lE; gbM	27
1929	Nova.	15 29 9·4	83 27 7	vF; vL; R; vgbM; r; diam = 9ˢ of time. With long attention it is seen to be composed of excessively minute stars like points rubbed out; and is in fact a globular cluster, but to see it thus requires long and perfect tranquillity of the eye. A very interesting object. (See fig 89.)	253
1930	III. 634	15 29 41·7	49 39 52	F; S; R; gbM; 12″; 2 very L stars follow	357
		44·6	40 25	eF; S; R; two **s 8 m, nf, dist 5′	73

No.	Synonym.	R 1890·0.	N.P.D. 1890·0.	Description and Remarks.	Sweep.
		h m s	° ′ ″		
1931	II. 762	15 30 9±	32 44 53	F; L; R; 40″; taken much past merid and P D only rough. R A per working list.	225
1932	Nova.	15 32 13·6	57 40 33	v F; S; R; b M; 12″	74
1933	II. 655	15 33 37·5	73 39 42:	v F; R	24
1934	II. 764	15 35 42·2	30 6 3	B; R; p s b M; r; 25″	225
1935	II. 425	15 37 43·6	87 2 54	v F; v S; R; 10″	427
		48·0	3 27	F; R; g b M; 20″	144
1936	III. 635	15 38 25·3	48 21 6	F; R; b M	155
		28·3	20 44	No description	156
1937	III. 636	15 38 29·9	48 20 21	p B; R; b M	155
1938	II. 97	15 39 17·6	71 34 49	p B; R; p s b M; 20″	334
		19·3	34 34	p F; R; g b M; 30″; between two coarse double stars	262
1939	II. 583	15 45 39·4	88 56 27	p B; S; l E in parallel; g b M	144
1940	Nova.	15 47 35·3	83 34 7	p B; p L; E; 30″ l, 18″ br	253
1941	Nova.	15 48 47·2	83 29 57	S; R; nearly stellar; but about 10″ at the centre has nearly a uniform light, and a burr surrounds it.	253
		55·2	30 44	p F; v S; R; much condensed in the centre. A disc with a burred border. Almost a planetary neb.	153
1942	III. 646	15 49 43·2	73 37 22	e F; v S	27
1943	III. 73	15 49 46·2	73 32 22:	e F; v S; in the same field with III. 646	27
1944	III. 622	15 56 28·7	52 10 30	Not v F; R; S; has * 12 m 40″ dist and 30° s f	72
		29·1	10 27	e F; S; R; has * 10 m 40° s f	71
		...	11 ±	e F; R. P D a mere guess	28
1945	Nova?	15 57 22·9	81 26 22	A * 7 m which I strongly incline to think has a nebulous atmosphere about 2′ diam.	253
1946	III. 637	15 58 34·2	48 51 4	p B; v S; R; b M; 6″ ... 8″ diam	156
		35·6	50 40	p B; v S; R; almost stellar or p s b M; diam 10″	155
1947	III. 553	16 1 17·4	88 50 12	F; L; p m E; v g b M; 2½′ l	144
1948	III. 74	16 2 44±	72 51 2	e F	27
1949	III. 889	16 6 9·6	56 30 56	v F; S; R; b M	74
1950	III. 888	16 9 7·8	57 36 35	v F; v g l b M; 30 ... 40″	258
		9·7	36 21	v F; S; R; b M.	74
1951	III. 688	16 10 15·1	53 52 33	No description	72
		16·3	50 59	v F; S; R	28
1952	II. 151	16 10 31·5	82 10 35	F; p L; l E; v g b M; 50″ l, 40″ br	153
1953	II. 402	16 12 58·4	91 52 32	e F; v L; oval; 3′ l, 2′ br; cloudy; 3m preceding nearly in the parallel is a fine double star.	146
1954	Nova.	16 13 39·9	51 48 33	v F; e S; R	72
1955	III. 623	16 13 46·1	51 49 14	v F; v S	73
		46·9	50 13	F; S; R.	72
		...	50 ±	Has a coarse double * 10° n f, 2′ dist (past merid. No R A observed, and P D rough).	71

No.	Synonym.	R 1830·0.	N.P.D. 1830·0.	Description and Remarks.	Sweep.
		h m s	° ′ ″		
1956	III. 624	16 16 58·5	51 40 19	v F; irreg R; r	28
		61·7	40 48	F; S; R; b M	73
1957	Nova.	16 19 20·5	48 40 29	F; R; b M; sky very clear	155
1958	III. 638	16 19 25·8	48 42 49	No description	156
		28·0	43 9	p B; R; b M; 20″	155
1959	III. 639	16 20 9·6	49 8 53	F; S; R	73
1960	II. 652	16 22 0·1	48 40 28:	v F; irreg R; among stars	155
		1·2	41 52	p B; p L; R; g b M; 40″	357
1961	II. 875	16 22 48·8	50 4 26	F; S; R	73
1962	III. 640	16 23 57·9	48 48 29	No description	156
		65·1	48 4	p B; S; R; b M; 12″. Probably a mistake of 5ˢ in reading the chronometer in one or other obs.	155
1963	III. 641	16 24 18·4	48 59 57	F; v S; R	73
		...	62 ±	Rough P D. Past merid	155
1964	III. 890	16 24 21·0::	54 33 57	F; irreg fig; r; 2 or 3 of its stars seen, also one 13 m 30″ dist n f. R A reduction fluctuating and uncertain in this sweep.	71
		27·9	34 8	v F; E; near a *	72
1965	Nova.	16 27 9·3	54 17 48	F; S; R; g b M; has a * 11 m 75° n p dist 40″ (by diagram).	72
1966	III. 893	16 30 41·4	50 37 31	v F; R; between 2 stars 14 m	357
		42·3	37 56	v F; S; between 2 stars	73
		...	38 ±	Seen. Rough P D. No transit	155
1967	Nova.	16 31 14·3	53 27 38	v F; v S; s m b M to a * 12 m; 12″	72
1968	M. 13	16 35 35·1	53 12 57	Very rich cluster; irreg figure; v L; v g m b M; stars 10 . . . . 15 m, of which there must be thousands; does not come up to a nucleus; has hairy-looking curvilinear branches. (See fig 86.)	71
		36·3	12 39	Irreg R with scattered stars in streaky masses and lines. Excessively condensed, to a perfect blaze. *s 11 . . . 20 m; 7′ or 8′ diameter. Most magnificent object. The state of compression indicates a globular form not much denser at the centre.	28
		39·7	12 45	A very fine and striking object, but nothing to add to the description of Sw 71.	72
1969	II. 701	16 37 13±	52 50 39	No description; R A a mere guess	28
1970	Σ. 5. N.	16 37 18±	65 53 ±	Struve's fifth nebula in the list at the end of the Dorpat Catal of D stars. v B equal to a star 8 or 8.9 m, 8″ diameter, and of a uniform light, but with the edges boiling and ragged. A fine object like a star out of focus. Viewed between clouds. Struve's place.	263
1971	M. 12	16 38 24·8	91 38 22	v rich globular cluster. The stars 10 . . . 16 m; v g m b M, but has stragglers in lines and branches extending some distance from the most condensed part, which is 3′ diam. Comes almost up to a blaze in the middle, and has a * 10.11 m in the centre.	146
		...	38 25	Irreg R; v L; 10′ diam with stars from 10 to 20 m	5
		...	.....	Viewed June 1, 1833. Very like M. 10, but the stars more separated and fewer. It is also rather larger. A fine object. Stars 10.11 . . . . . 15 m.	—

Fig. 86.

No.	Synonym.	R 1830·0.	N.P.D. 1830·0.	Description and Remarks.	Sweep.
		h m s	° ′ ″		
1972	M. 10	16 48 10·8	93 50 ±	A globular cluster of scattered stars, but twilight and moon interfere. (P D from another sweep, not having been taken.)	75
		14·3	49 42	Is brighter than 12 M and rather larger and looser. (*This* disagrees with an obs of 12 M.) The bright part = 4′, but the cl fills two thirds of the field = 10′. Stars 9 . . . 15 m.	146
		. . .	. . . . .	L; roundish; g p m b M; 10′ stars 15 . . . 20 m	5
		. . .	. . . . .	Viewed June 1, 1831. A superb cluster of very compressed stars, g b M. The stars are 10 . . . 15 m, and run up to a blaze in the centre, but I see no nucleus. Diam about 6′; a noble object.	—
1973	III. 689	16 48 44·0	53 13 47	e F; v L; E in parallel; 2′ l, 1′ br	71
1974	Nova?	16 49 11·3	50 6 39	A suspicious object. It is pointed to by a F double ✱ n f. Doubtful whether a nebula or a v F double star, with perhaps a third star near (of course ill seen).	357
1975	M. 19	16 52 6·9	116 0 0	A fine globular cluster, stars v S, 12 . . . . 18 m, with one = 10m, and one 10.11 m; nearly R; v g p m b M, but does not come up to a blaze (*i. e.* to a confusion of the stars with one another). Insulated; 3′ diam. It forms a link between I. 70 and 10 or 12 M.	148
		. . .	. . . . .	Viewed July 1, 1823. F; R; g b M; r; fills ¼ field; one or two ✱s seen, but the twilight too strong.	—
1976	VI. 11	16 54 7·1	114 30 52	B; L; b M; r; but too much twilight	30
1977	VI. 12	16 59 35·7	116 20 10	v B; R; p s b M; 90″; resolved; the stars are 19 or 20 m. This then is entitled to the name of a globular cluster.	148
1978	Nova.	16 59 42·7	116 20 5	F; S; v s b M; is a companion to the globular cluster VI. 12.	148
1979	M. 9	17 9 6±	108 20 ±	R; v g l b M; 3 or 4′ diam; v faintly seen in strong twilight. R A from Catal. P D very roughly determined.	269
1980	II. 767	17 13 16·0	17 30 2	v F; R; g b M; 25″ s f a small d ✱ 2′ dist	428
1981	IV. 11	17 18 59·8	113 36 9	p B; R. Planetary?	30
		64·5::	35 39	p B; R; 40″. Twilight	31
1982	I. 44	17 28 16·8	113 47 36	A neb, with a p B star attached	30
		20·5	47 31	No description	31
1983	M. 14	17 28 42·3 :	93 8 25	A globular cluster; v L; 8′ or 10′ diam; the stars so excessively minute as to be scarcely discernible. A striking object. Place probably very inaccurate.	5
1984	Nova?	17 36 55·3	114 48 59	A cl of v S stars. Twilight	30
1985	I. 150	17 38 45·5	110 17 33	p B; R; g b M; 60″. Strong twilight	269
		. . .	. . . . .	Viewed; p B; p L; p s b M; 90″; easily found by the working list.	268
1986	II. 586	17 39 7·5	109 57 55	p B; p L; R; r; 40″	268
		8·5	56 38	p B; R; g b M; 60″; a star 15 m n p	269
1987	III. 741	17 39 43·9	17 48 32	v F; v S; R; b M; 6″; 90″ n of ✱ 8 m	428
1988	Nova?	17 42 25·6	115 20 54	Suspected; small; twilight	30
1989	Nova.	17 44 42·5	66 52 41	A S, R, very perceptible disc 1″ or 1½″ diam, with a v F nebula surrounding it—among many stars 12 and 14 m, none of which are so affected. A curious object. (See fig 42.)	266

Fig. 42.

No.	Synonym.	Æ 1830·0.	N.P.D. 1830·0.	Description and Remarks.	Sweep.
		h m s	° ′ ″		
1990	M. 23	17 46 41·8	108 61 45	A v L, p rich, coarse, scattered cluster which fills the field. Stars 11 and 12 m.	276
		61·0	57 48	A star 10 m in centre of a beautiful discrete cluster of 60 or 70 stars 10 and 11 m and one of 9.10. They run in lines and arches. It is loose and straggling, and the sky around has a? dotted appearance.	269
		61·9	58 18	A v large, coarse, straggl cluster of about 100 stars 9.10...13m. It is announced several minutes before by an increased number of stars in the field.	33
1991	IV. 41	17 51 56·9	113 1 29	The double star Sh 379 in the centre of the trifid nebula IV. 41. (See my 5th Cat of double stars. Mem. R.A.S. and fig 80.)	275
		62·4	0 41	A careful drawing taken, but the neb is not clear from twilight and clouds. (N.B. This drawing is unfortunately lost, and that engraved in fig 80 is constructed from much less elaborate sketches, aided by memory.)	32
		64·3	0 6	v L; trifid, three nebulæ with a vacuity in the midst, in which is centrally situated the double star Sh 379, neb = 7′ in extent. A most remarkable object.	30
		...	0 43	Seen in its place, but clouds prevented observation.....	31
1992	Nova.	17 54 3·6	78 56 57	A coarse and poor cluster of L stars.....	196
1993	M. 21	17 54 25±	112 30 2	A tolerably rich, sc, coarse cl; one * 9 m, the rest 10....12..	275
1994	II. 197	17 56 51·5	115 0 52	F; L; l E; b M; resolved.....	30
1995	Nova.	17 59 5·3	108 26 52	A v coarse and scattered but p rich cluster of L and S stars. Has several double stars in it.	268
1996	Nova.	17 59 33·3	114 7 27	Several stars affected with nebulosity: the brightest taken ...	30
1997	VIII. 54	18 0 40·4	106 49 7	Large poor straggl cluster. No other near the place of VIII. 54.	163
		...	45 ±	Very coarsely straggling and loose, hardly entitled to be called a cluster. The place (roughly taken) is that of 2 or 3 bright stars.	36
1998	VII. 30	18 2 32·3	111 36 10	A v L, v loose clus, pretty rich, fills the field; stars 11...13 m	275
1999	Nova?	18 3 35±	112 11 4	A cluster composed of 2 or 3 clusters of very small stars, and loose large ones. Perhaps this is an outlier of VII. 31.	275
2000	Σ. Neb. 6	18 3 50·4	83 10 57	A beautiful round, perfectly well defined and brilliant disc, equalling a * 8.9 m. White equably bright. Well seen in broad morning twilight. A * 9.10 m follows, 2′ dist. The sweeping power shows it as a * of large diameter, which could not escape examination in a good night; with 240 the disc seen as described. It cannot be more than 4″ diam.	153
		...	11 24	B; R; 8″ diam; rather hazy at the borders. It is something between a planetary neb and a B R neb. The light is pale and dull, but stellar, and equals a * 8.9 m. Two stars follow, the nearest distant in R A 14ˢ·5. A fine and curious object. On long and careful attention I cannot get rid of the hazy border and reduce it to a sharp round disc.	279
		...	.....	Just caught in the evening twilight and shown to M. Struve the moment of his arrival at Slough, Aug 19, 1830, having travelled together from London.	282
2001	VII. 31	18 5 37·1	112 10 26	P rich; 3 or 4′ diam; irreg fig; the stars v S	30
2002	Nova.	18 7 1·3	109 55 12	A double star in a faint neb. (See fig 30.) A very remarkable object.	270
		...	55 38	An oval nebula, involving a fine double star (N° 2827 of my 5th Catalogue,) for which see further descriptions.	269
		...	55 56	A double * h. 2827 involved in a p B large nebula 50″. See description of that *.	268

Fig. 80.

Fig. 30.

No.	Synonym.	Æ 1830·0.	N.P.D. 1830·0.	Description and Remarks.	Sweep.
		h m s	° ′ ″		
2003	VIII. 55	18 7 44·0	106 41 50	A cluster with a triple * in it	274
2004	M. 24	18 8 27·5	108 28 13	A glorious concentrated part of Milky Way, almost amounting to a globular cluster. Stars 14 and 15 m.	269
		28·9	29 2	Fine cluster of stars 15 m; R; 6′; the stars are all of a size. The cl seems connected with the Milky Way.	270
2005	Nova.	18 8 38·0	105 0 8	Loose straggling cluster; stars 10..12 m	34
2006	M. 16	18 9 15±	103 50 34	No description	34
2007	M. 18	18 10 ±	107 11 42	A poor and coarse cluster. Contains about a dozen stars 10 m and 15 or 20 more 12..15 m.	270
2008	M. 17	18 10 44·2	106 17 55	The principal star in the preceding arc of the horse-shoe-like portion of the nebula M. 17. See fig 35.	163
		46·8	14 5	The small insulated, resolvable knot in the preceding, strait branch of the neb.	274
		51·8	14 19	The same knot. See description of this neb in the Appendix. See also the figure.	358
		...	15 48::	A most curious object, not unlike the nebula in Orion (as it used to be figured, like a Greek capital omega, Ω.) There is in it a resolvable portion or knot distinctly separated from and insulated in the rest as if it had absorbed the nebula near it. (A figure carefully drawn.) (The P D inaccurate, being much past merid.)	33
		...	15 27::	A large extended nebula. Its form is that of a Greek Ω with the left (or following) base-line turned upwards. The curved (or horse-shoe) part is very F, and has many stars in it. The preceding base-line hardly visible. The following, which is the principal branch, occupies nearly half the field ($7\frac{1}{2}'$.) Its light is not equable, but blotty. Strong twilight.	48
2009	Nova.	18 13 40±	102 6 42	A loose straggling cluster of stars 11..12 m	34
2010	M. 28	18 14 4·7	104 57 29	Not v B; but v rich, excessively comp globular cl; stars 14..15 m; m b M; a fine object.	30
2011	Nova.	18 21 23·0	103 16 16	A closely clustering portion of the Milky Way, which is one continued cluster here.	34
2012	II. 205	18 21 32·8	113 34 37	p B; R; g b M; 40″	30
		35·2	35 7	A beautiful little globular cluster of excessively minute stars, 60″ diam; seen in twilight. It must be p B when seen in dark night. (Sky very pure.)	275
2013	VI. 23	18 22 47·2	107 0 11	A rich, p comp cluster; irreg fig having a vacancy in the middle; stars = 11..15 m.	36
2014	VIII. 14	18 23 20±	107 27 11	A very loose parcel of v small stars, hardly noticeable as a cluster	36
2015	M. 22	18 25 59·1	114 1 16	A magnificent globular cluster; g b M but not to a nucleus. The stars from 12 to 20 m. Those 12 m are equally scattered over it, but those of 20 m form the central mass.	30
		61·2	1 11	A superb, v m comp, R cluster. Stars 11..15 m; not very well defined. Rather more comp to the n f side than at centre; admirably seen in twilight.	275
2016	Nova.	18 26 50·6	66 33 38	A v poor cluster 8th class	266
2017	Nova.	18 32 34·3	94 55 2	A L p rich cl of straggling stars, having a vacuity in M and broken into 2 or 3 clusters. Fills field. 70 or 80 stars of all magnitudes from 10 to 18 counted. Extended, in parallel. The most comp part f.	83

Fig. 35.

No.	Synonym.	R 1830·0. h m s	N.P.D. 1830·0. ° ′ ″	Description and Remarks.	Sweep.
2018	Nova.	18 33 4·5	96 22 46	A more than usually condensed portion of the enormous cluster of the Milky Way. The field has 200 or 300 stars in it at once.	84
2019	M. 11	18 42 0·1	96 27 42	A beautiful irregularly R cl 10′ or 12′ diam. The stars are all 11 m except one = 9 m whose place is taken. Examined with high magnifiers [I have often viewed it with 800 and even 1200]; it is broken into 5 or 6 distinct groups with rifts or cracks between them.	82
		1·1	28 27	A glorious object. The bright * 9 m out of the centre taken.	85
2020	Nova.	18 43 27·4	79 51 0	A p considerable cl; 15′ diam; irreg fig, 50 or 60 stars large and scattered. The place is that of the double * No. 870 of my third catalogue.	88
2021	Nova.	18 44 31·0	110 6 12	A p rich cluster, figure like the letter S, 7′ in extent. Stars 9. . . . 13 m. Counted 40 of them.	268
2022	III. 143	18 44 50·3	112 54 20	A little knot of 8 or 10 stars crowded together. It is 1′ 40″ south of υ^2 Sagittarii, and on same meridian.	30
2023	M. 57	18 47 13·2	57 10 37	The annular nebula in Lyra. The diameter of the ellipse in R A = 6ˢ·5 : : It has a small star f exactly on the parallel of the centre, and distant from the edge rather more than the breadth of the ring.	198
		13·4	11 7	Annular neb between β and γ Lyræ. Pos of longer axis of annulus = 57°·0 by microm. The small * f is almost exactly on the parallel of the centre, dist about = breadth of ring. The central vacuity is not *black*; a nebulous light fills it. The edges are not *sharply* cut off, very slightly ill defined. See fig 29.	197
		17·6:::	11 31	R A not good, the sweeping zero having been interrupted by the disturbing effect of the side motion in viewing objects.	199
		. . .	13 ±	No R A, very rough P D; viewed; diameter in R A = 5ˢ·375 by a mean of 4 careful obs. The star following it = 11 m. It follows the centre 4ˢ·31, and its pos from centre = 96°·4 by microm. The neb has a mottled look. [N.B. This mottled look, however, is something quite different from the appearance called resolvable.]	168
2024	Nova.	18 49 ±	79 51 30	A cluster discovered with the 7-feet equatorial, Sept 5, 1828.	—
2025	Nova.	18 52 0·5	90 41 27	A considerable cl; not rich, but fills the field. *s = 12 m; place that of a double * No. 874 of my third catalogue.	80
2026	Nova.	18 52 13·8	108 46 32	A * 10 m in a p rich, roundish cluster 8′ diam; stars 12 . . . 15 m.	268
2027	Nova.	18 53 25·7	78 37 43	The central star (double) in a coarse and poor cluster.	196
2028	Nova.	18 54 47·7	60 58 3	A p L, poor cl of stars forming irreg groups or patches, 11.12 m; diam = 8′.	159
2029	Nova.	18 56 25·5	88 27 44	A cluster of loose small stars of various magnitudes; fills the field.	78
2030	VII. 19	18 59 18·7	86 1 39	A cl of small stars; fig irreg	78
		21·7	0 53	A v L, v rich cl, composed of 2 or 3 clustering groups running together; place that of the most condensed part.	278
		22·8	3 22	L, loose cl; fills field; the most condensed part is 3′ in extent. Stars = 12. . 14 m.	77

Fig 29.

No.	Synonym.	Æ 1830·0. h m s	N. P. D. 1830·0. ° ′ ″	Description and Remarks.	Sweep.
2031	VII. 62	19 0 16·4	85 35 ±	Pretty compressed cl; irreg fig, P D by the Sweep 77 being out of the limits of the sector.	79
		18·5	.....	Pretty rich; S; m compressed; oval or rather fan-shaped. The stars 11 . . 12 m, 4′ in extent; the n f side most comp.	278
		...	35 26	p comp; irreg fig; 2′ diam; st 15 m.	77
			32 49	p comp; S; R or irreg; taken out of merid.	78
2032	IV. 14	19 5 39·1	92 60 9	v F; R; v l b M; r; 30″. Nothing observed about it remarkable enough to entitle it to a place in class IV.	82
		42·3	59 54	v F; L; R; v l b M; diam in R A = 4ˢ·5.	83
2033	Nova.	19 6 34·7	85 25 8	Coarse; not very rich; eighth class	278
2034	Nova.	19 6 55·2	106 33 35	A fine, L, loosely scattered cl of large with some small stars. Fills 2 or 3 fields.	274
		...	30 ±	A very large straggling space full of loose stars, 8, 9, and 10 m	163
2035	Nova.	19 8 5·0	91 12 51	A cluster; poor; loose; irreg fig; stars 10 and 11 m	81
2036	M. 56	19 9 46 ±	60 6 6	A * 9 m precedes, about 1′ diam. (The R A in these early sweeps is liable to great errors.)	8
		52·1::	6 37	Fine; v compressed; m b M; stars 11 m; a * 9 m precedes. Clouds interfered.	197
		55·8	7 8	p rich; S; irreg R; g b M but not to a nucleus; 2½′ to 3 diam; stars 13 and 14 m, well seen in full illumination of field. A few scattered stars.	159
		56·6	7 10	L; R; v g b M. I see the stars which are v S and of different sizes. It fades gradually away at the borders.	7
		57·1	6 50	No description	199
		58·3	6 49	Fine comp cluster; R, inclining to a triangular form; b M; stars 12 . . . 14 m. A fine object, diam 3′.	198
2037	III. 743	19 10 9·4	83 45 19	A most beautiful, v L, F planetary nebula. Diameter in R A = 6ˢ·5 = 1′ 37″; its light nearly uniform, only very little hazy at the edge and perhaps rather brighter at the southern limb. Its nature seems to have been overlooked or mistaken by my Father, who has placed it in his third class. In Milky Way. Many stars in field, one 11 m near the n f limb.	280
		...	46 29	Pos of the small * near the edge, from the centre = 53°·0 by microm.	281
2038	Nova.	19 11 50 ±	91 24 34 :	An e S stellar neb = a * 15 m; it is ⅓ of a diam of field (= 10′) from a double star which it follows, to S. Pos from the star = 240° ±. The R A is excessively loose.	5
2039	VIII. 81	19 15 56·3	68 9 23	Has a double star h. 886 in it	267
		56·9	8 53	Coarse, poor cluster; stars 10 . . . 11 m. The southern of a group; is a first class double *.	266
		57·5	10 2	Place that of a double * at the northern extremity of the more condensed part of a L, loose, poor cluster of st 10 . . . 15 m.	90
2040	Nova.	19 17 36·7	86 48 13	The first of 3 stars 9 m, nearly in the parallel, joined by a rich clustering portion of the Milky Way.	278
2041	VIII. 21	19 20 7·8	65 11 55	v L; p rich; very straggling; stars 10 m; fills field.	167
2042	VI. 14	19 23 10·0	70 5 7	A rectangular cluster, v m comp; 3′ or 4′ l, 2′ br; stars 14 . . . 18 m; among B stars.	364
		10·2	4 57	e F; p L; v g b M; 4′ l, 2′ br; composed of stars 17 or 18 m. .	362
		12·6	4 6	A curious object, 4′ l, 1½′ br, extended in merid. The largest st 16 m	90

No.	Synonym.	R 1830·0.	N.P.D. 1830·0.	Description and Remarks.	Sweep.
		h m s	° ′ ″		
2043	VI. 38	19 23 25·4	81 7 10	A cluster. Has a * 16 m, one or two 18 m, and neb	89
		26·1	7 17	A very small compressed fan-shaped cluster of stars 11 ... 18 m, diam = 1′; a * 11 m on the n f side forms the vertex of the fan.	280
		26·6	7 22	Doubtful if a resolved cl or a neb of first class. p L; R; b M; 60″; with 2 or 3 accidental stars of the Milky Way.	88
		28·5	7 22	A v S roundish cluster, 40″ diam, of v S stars, one brighter than the rest and = 15 m. It is like a nebula well resolved, and is a curious object.	196
2044	Nova.	19 32 21·0	43 64 41	A double * in the southern part of a fine, large, pretty rich, coarse cluster of about 100 stars 11 .... 14 m; it fills the field.	205
		64·9	58 50	The centre of the more condensed part of a considerable cluster, 10′ diam, of irregularly scattered stars.	206
2045	III. 744	19 33 21·0	100 42 35	Not v F; p L; R; b M; r; 50″	86
2046	Nova.,	19 33 53±	63 35 ±	v L, p rich, straggling cluster; it more than fills the field. Stars 10 ... 15 m.	167
2047	IV. 51	19 34 20·3	104 32 37	Planetary nebula. B; R; equals a * 9 m in its light; diam = 10″ by estimation. Perfectly round; there is no central vacuity (power 320). The light, though not hazy, is turbid, not like stars, but a kind of curdled appearance, very singular. Has two stars very near. The nearer, A, 15.16 m; pos 309°·5, 312°·8, 313°·0; the first measure taken with 320, and better than the others. The further, B, 15.16 m; pos 82°·1, 78°·0 (with 320). Dist of A 30″, of B 50″. (See fig 46.)	365
		21·3	33 29	Exactly R; = * 8 m; disc = 10″ or 12″ in diam; has 2 stars 12 m near. Pos of A = 307°·0, of B = 81°·5. Central measures. Light equable, and disc very lucid, yet a little (not hazy, but) as if boiling at the edges, with a suspicion that it may not be well defined.	163
		22·7	32 54	Exactly R; diam estimated at 8″; the light equable and equals a * 6.7 m. It is exactly like a planet and two satellites. Distance of A, the nearer, 20″, Pos 45° n p; of B, 25″, 20° n f.	34
2048	Nova.	19 35 22·7	50 12 7	A beautiful cluster, v rich, v L; stars 11 ... 15 m and 1 = 7 m n f, a reticulated mass, central part = 4′, but fills field with its loose stars. A very fine object.	359
2049	VII. 18	19 35 56·9	67 5 58	p rich, irreg R; 5′ diam; a cl of loose stars; the chief = 10 m, the rest = 11 ... 12. Four or five in centre form a lozenge.	266
2050	IV. 73	19 40 18·8::	39 54 0	A most curious object. (See fig 43.) A * 11 m surrounded with a v B, perfectly R planetary neb, of equal light throughout. Diameter in R A = 3ˢ·5. Perhaps a very little hazy at the edges. With 320 the * is not seen double.	207
2051	VIII. 73	19 42 2·6	82 30 40	A * 8 m in a poor cl, hardly to be called a cluster. (Night very bad.)	89
		...	31 ±	Coarse; straggling; 15′; not remarkable; chief * = 9.10 m..	88
2052	VII. 9	19 43 47·2	67 20 14	Fine large coarse cl; fills field. Stars 11 ... 12 m, some outliers = 9, 10 m.	266
2053	Nova.	19 45 11·5	31 0 24	A * 7 m in midst of a field full of 40 stars 10 ... 12 m	366
2054	VIII. 16	19 45 21·6	61 1 38	Coarse irreg R; with detached portions of smaller stars. Those in the main cluster = 11 or 12 m.....	7
2055	VIII. 18	19 45 28±	78 45±	Viewed. In place by working list? It is a coarse straggling part of the Milky Way.	196

Fig. 46.

Fig. 43.

No.	Synonym.	Æ 1890·0.	N.P.D. 1890·0.	Description and Remarks.	Sweep.
		h m s	° ′ ″		
2056	M. 71	19 46 5·7	71 41 14	v rich; m comp; g b M; an irreg R cl of v S stars, inclining to triangular form. In a rich part of Milky Way.	360
		8·0	38 31	v L; loose; fills field; a fine object; stars 11 . . . 16 m; the most condensed part = 3′, of an acute triangular figure, the angle northwards.	90
		12·1	38 42	An irreg R mass of closely packed st; g b M; 3′ or 4′ diam; a decided cl; but towards the s p the Milky Way is immensely rich.	364
2057	VI. 16	19 46 53±	72 33 ±	A quantity of Milky Way stars, immensely close, one small patch of which may be the cluster VI. 16.	362
		. . .	. . . . .	An insignificant bunch of little stars in the Milky Way. Hardly more marked than the general mass, which is astonishingly rich here.	92
2058	VIII. 19	19 47 17·0	78 20 12	A small, poor cluster; the preceding of two distinct clusters. The stars 11 m.	196
		. . .	. . . . .	Viewed. Is a coarsely clustering part of the Milky Way	125
2059	Nova.	19 48 7·0	78 17 12	A poor, small cluster. The following of two, just alike	196
2060	M. 27	19 52 8·6	67 43 ±	(See fig 26.) A nebula shaped like a dumb-bell, with the elliptic outline completed by a feeble nebulous light. Position of the axis of symmetry through the centres of the two chief masses = (by microm) 30°·0 or 60° n f . . s p. The diam of the elliptic light fills a space nearly equal to that between the wires (7′ or 8′). Not resolvable, but I see on it 4 distinct stars 1 = 12 m at the s f edge; 2 = 12.13 m, almost diametrically opposite; 3 = 13 m in the n p quarter, and 1 = 14.15 m near the centre. Place that of the centre.	166
		10·0	45 11	Place the most condensed part of the southern head; diameter in R A = 25ˢ·0. A most extraordinary object; v B; an unresolved nebula, shaped something like an hour-glass, filled into an oval outline with a *much* less dense nebulosity. The central mass may be compared to a vertebra or a dumb-bell. The southern head is denser than the northern. One or two stars seen in it.	90
		13·3	44 7	I showed a friend the oval filling up of the outline of this strange object as delineated in Sw 266, and he saw it well.	267
		15·0	44 14	Like a double-headed shot or a dumb-bell. The light perfectly milky; the s p head is a v l the brighter. The outline is filled up elliptically with a F nebulosity as in figure, which, I think leaves ansæ as if inclined to form a ring. Two S st in it and many more near, one close to edge (No. 1 of Sw 166). A most amazing object. Position of greater axis of the elliptic outline = 117°·1; of axis of symmetry 31°·4 (microm).	266
2061	Nova.	19 54 58·2	79 12 19	A pretty rich oblong cl; 10′ l, 5′ br; stars equal and of 13th mag. In Milky Way. Place that of a double ✻.	196
2062	III. 144	19 55 12·4	56 54 26:	A small bunch of very minute Milky Way stars, so small as almost to look nebulous; n p is another.	199
		13·9	56 23	A nebulous-looking patch; 12″ diam; in Milky Way; ill-defined; perhaps only some e minute stars mixed with larger which are distinct.	198
		15·0	56 21	F; S; R; among a field full of stars.	168
2063	Nova.	19 55 28·2	34 20 3	A small pretty close cluster; irreg R; 3′ diam; stars 12 . . . 16 m.	211

No.	Synonym.	R 1830·0.	N.P.D. 1830·0.	Description and Remarks.	Sweep.
		h m s	° ′ ″		
2064	M. 75	19 56 2·5	112 23 31	v B; R; v s v m b M; 2′; a bright R ball 15″ diam, in an atmosphere 2′; 3.20 does not show the stars but makes it more resolvable.	369
		2·7	23 38	p B; R; p s v m b M; r; 90″	298
		2·9	24 10	Not B; S; R; p s b M; 2′ diam; r, but not resolved. An insignificant object.	275
2065	Nova.	19 56 12·0	94 1 59	A little compact knot of 7 or 8 stars taken at first for a nebula, (and liable to be mistaken for one hereafter). Stars 19 m.	83
2066	VII. 59?	19 58 12·2	46 28 50	A coarse rough cluster. Taken for VII. 59, but the place does not agree.	203
2067	Σ. 2630	19 59 30·6	54 42 17	A double ✱ Σ. 2630, in a cluster of 5 bright and many small stars.	168
2068	Σ. 2631	20 0 45·7	69 23 2	A double ✱ the chief of a coarse straggling group of stars 10.... 13 m, hardly entitled to be called a cluster.	362
2069	VIII. 86	20 1 39·0	52 14 43	A coarse scattered cluster of about 60 stars. The largest (10 m) taken.	200
2070	Nova.	20 4 51·5	54 39 36	A double ✱ in a cluster of a good many stars 10 ... 13 m	168
2071	VIII. 20	20 4 51·7	64 1 10	Splendid cluster. More than fills the field; loose and straggling; poor in stars, one = 6.7 m whose place is given; the rest 9, 10, 11.	167
2072	IV. 13	20 9 31·6::	59 59 ±	Planetary nebula; diam [by inexperienced estimation] = 1′; light equable, exactly round; v F, a mere ghost; P D roughly taken and of no value. Sept 4, 1825.	7
		32·9	57 16	e F; 15′ diam; strongly suspected to be annular, but the darkness in the centre is not striking.	199
		33·5	56 43	e F; annular; pretty sharply defined; a very little elliptic; the northern limb is the brightest; the darkness in the middle requires some attention to see, but once seen it cannot be mistaken. A most curious object, resembling much the annular nebula in Lyra, but rounder, smaller (not above half the diameter,) and far fainter. (See fig 48.)	198
		...	.....	Viewed Sept 7, 1825, past merid, the transit being missed owing to its faintness. It is exactly R, but decidedly brighter at the edges than in the middle. It is a round miniature of the annular neb in Lyra (40″ estim diam,) having a darkness in the middle. I made my assistant come up and look at it. He said it had a hole in it. (N.B. Much better seen than last night (Sweep 7), and more attentively examined.)	8
2073	Nova.	20 13 55·5	109 50 39	A ✱ 10 m, with a considerable nebulous appendage s p, in which by glimpses may be fancied a star 15 m.	268
		56·5	51 35	A ✱ 10 m, with a nebulous wisp, in which by glimpses a ✱ 18 m may be seen; pos = 194°·9 by microm. A very curious object.	297
		56·6	50 22	A ✱ with a nebula attached in which is a small ✱ or nucleus 17 m.	270
2074	Nova.	20 14 29·7	64 47 10	A small straggling cluster of stars 10..11 m. One of the 9 m, whose place is taken.	167

Fig. 48.

No.	Synonym.	R 1830·0. h m s	N.P.D. 1830·0. ° ′ ″	Description and Remarks.	Sweep.
2075	IV. 16	20 14 46·1	70 26 7	Fine planetary nebula; B; exactly round; rather hazy at the edges, but not materially brighter in the middle, but *no hollow*. It has four small stars near it like satellites. (See fig 47.) Pos of B = 358°·0 by micr, dist estim 30″, 10 m; of D pos = 41°·2, 60″, 13 m. Clouded suddenly before I could measure the others.	364
		48·0	25 40	Exactly R; F; diam = 2ˢ in R A = 30″±. Its light is a little mottled, but it is well defined. Lies between 2 stars, but nearer to the southern (A) than to the northern (B); A is 85° s f (*i. e.* pos = 175°), and the centre of the neb is $\frac{1}{10}$ of its diam to the preceding side of their line of junction.	90
		48·8	26 7	Fine planetary nebula. R; diam = 18 or 20″; a little hazy at the edges, or rather pretty much so, so as to be ill defined. Has 4 stars near; one of them (B) = 10 m, pos = 359°·0; dist 40″; another (C) = 11 m, pos = 104°·8, 60″; another (A) is very nearly in a line with B and the centre, perhaps a degree or two to the following side; the neb is pretty bright.	362
2076	III. 141	20 14 56·5	115 20 32	v F; L; R; v g l b M; 3′ diam; r; the sky hazy.....	289
2077	VIII. 56	20 17 0·8	49 44 48	A poor and coarse but rather brilliant cl, 2 st 9 m (the n p taken) and 30 or 40 more 10....12 m.	183
		2·0	49 ±	A fine cluster of about 30 stars, one = 8 m taken, (but very coarsely); one = 9 m, and many stragglers 10....16 m.	201
		12·9	47 7	p B; S; the stars are 11 m, and two are 7.8 m. Place that of the s f. 40 stars counted, 5′ long, 3′ broad.	359
		...	50 ±	A fine close cluster of p L stars, not rich; irreg fig.....	180
2078	M. 29	20 17 45·5	52 1 48	A coarse cluster of 8 large stars (10 m), and a dozen or 20 smaller in a roundish form. (Milky Way.)	200
2079	III. 142	20 24 16·6	92 35 51	v F; p L; l E in merid; the n p of 2	81
		20·6	35 38	v F; p L; p m E; or two joined; nearly in the meridian	288
2080	Nova.	20 24 33·1	92 36 51	v F; v S; the s f of 2.....	81
		36·5	36 8	v F; among small stars	288
2081	I. 103	20 25 50·8	83 9 39	Globular cluster; diam in R A = 4ˢ; all well resolved; p g b M; a * 9 m precedes 7ˢ·5.	281
		51·9	9 55	Observed with M. Struve the evening of his arrival at Slough.	282
		52·1	9 37	A beautiful, v compressed, B, R, globular cluster, 3′ diam, well resolved. Stars = 16....20 m. A p B * p.	280
2082	VII. 17	20 27 15·6	68 20 ±	Place of the chief * 10 m of a coarse, poor, straggling cluster	166
		...	23 ±	Very poor. The large star taken but carelessly, as it offers no interest.	90
2083	VI. 42	20 27 56·4	29 56 37	A * 11 m with a rather poor cluster of stars 12....15 m; ☾ near full, but probably in dark night a rich cluster, 5′ in diam, fan-shaped, and a B * at the point.	218
		59·6	55 42	Fine, rich, p compressed cluster; 5′ diam; stars 11...13 m, rather convex on the p side.	367
		64·3	55 44	Very fine rich cluster; 5′ diam; stars 12 m and nearly equal; shape rather convex towards the preceding side.	366
		72·1	.....	Very fine rich cluster; stars 11....16 m, (not stated what part of the cluster taken, probably the middle; whereas the foregoing observations evidently refer to the preceding bright star).	214

No.	Synonym.	Æ 1830·0.	N.P.D. 1830·0.	Description and Remarks.	Sweep.
		h m s	° ′ ″		
2084	IV. 76	20 31 16·9	30 26 2	a v F, v L patch, no doubt a cluster 8 or 10′ in extent, v g v l b M; but I cannot see the stars.	367
		18·9	26 14	v F; e L; v g l b M; r; 5′ or 6′; irreg fig. A curious object; no doubt a great cluster of e F stars. Requires the eye to be well prepared for seeing it.	366
		21·7	27 11	v F; v L; v g b M to near the middle, and then p s b M; 8 or 9′ diam; is barely resolvable; seems to be an enormous cluster, immensely distant.	214
2085	VIII. 23	20 33 17·6	73 56 54	Poor, large, scattered cl; the brightest * = 10 m.	92
2086	III. 219	20 35 48·6	78 5 58	v F; S; 15″ precedes and is attached to the double star No. 1566 of my fourth catalogue.	196
2087	II. 426	20 38 35·1	90 18 16	p F; S; R; g b M; 15 . . . 20″	81
		36·2	17 8	e F; S; R; l b M; 12″	294
2088	V. 15	20 38 38·6	59 53 30	The place is that of k Cygni, through which the nebula passes. It is very long and winding and runs northward from k full 2 fields' breadth (30′). One branch is pretty conspicuous, even in a little moonlight. The nebulosity is milky, and does not seem to arise from small stars of the Milky Way ill seen.	178
		38·9	53 56	The neb extends southwards far beyond k Cygni, but is e F; the northern part is p B (at least in a very clear night) and extends to two stars. P D = 59° 26′ 56″. [A drawing made, which with others made since has served for the construction of fig 33, which represents this extraordinary object.]	199
		38·6	. . . . .	Northwards from k Cygni 27′ extends a curved tail of nebula of a serpentine form, fading very gradually into two tails forming a fork. Its general direction is in the meridian. Barely attains k Cygni, and is there of extreme tenuity. Requires a fine night and the eye well prepared by at least 3m exposure to darkness.	198
2089	II. 427	20 38 41·1	90 19 36	F; v S; R	81
		41·7	18 33	e F; v S; 6″	294
2090	M. 72	20 44 5·1	103 10 26	F; R; g b M; resolved into very small stars; 2 or 3′ diam. . . .	10
		5·8	10 9	p B; v compressed cluster; irreg R; barely resolved; v g b M; 3′ diam; many straggling stars near, but none so small as those of the cluster.	365
		6·5	10 13	F; R; 2′ diam; g b M; r, but I do not see the stars separated enough to count them. Sky beautiful. Has a * 9 m 30° s f, dist 3′. Is rather an insignificant object.	34
2091	VIII. 76	20 48 51·0	43 22 10	A star 9 m; the largest of a cluster	210
		77·6	18 22	A * 11 m. The last of that magnitude in an irregular triangular cluster 6′ diam; poor and straggling.	209
2092	V. 14	20 49 19·1	58 57 1	Place of the southern and brightest star of a trapezium south of the bifurcation of this nebula. The neb is e F, v L, and straggling, extending at least 4 fields (= 1°). Its direction is (by diagram) about 20° n p to s f, and near the middle it forks into two chief branches. (See fig 34.) In the trapezium (or oval) above spoken of are 6 stars 1 = 11 m; 2 = 10 m; 3 = 12 m; 4 = 14 m; 5 = 15 m; 6 = 12 m. The northern branch of the fork is the principal, and passes s of a double * (7).	199

Fig. 34.

See next page.

No.	Synonym.	R 1830·0. h m s	N.P.D. 1830·0. ° ′ ″	Description and Remarks.	Sweep.
		22·7	.....	The same star in the nebula V. 14. The nebula is of great extent, passing obliquely through and rather under (to the s of) a small constellation, being densest where under it; but it is extremely F and only to be seen with an eye well prepared and in a very clear night. The whole neighbourhood seems affected with wisps or cirro-stratus-like masses of nebula.	198
2093	Nova.	20 50 4·4	60 26 6	(See figure 82.) A most wonderful phenomenon. A very large space 20′ or 30′ broad in P D, and 1^m or 2^m in R A full of nebula and stars mixed. The nebula is decidedly attached to the stars and is as decidedly not stellar. It forms irregular lace-work marked out by stars, but some parts are decidedly nebulous, wherein no stars can be seen. A figure (from which the drawing for the engraving was copied,) represents general character, but not the minute details of this object, which would be extremely difficult to give with any degree of fidelity.	8
2094	VIII. 82?	20 50 28·0	45 10 50	Coarse, poor, p L cluster; stars small	203
		...	.....	Viewed. A mere clustering portion of the Milky Way	189
2095	Nova.	20 52 22·0	90 51 31	e F; S; E in the meridian	81
2096	V. 37?	20 53 12±	46 20 ±	An immense nebulosity all around this place, but too ill defined to fix the limits. R A that of V. 37, from working list, not being settled by the obs.	203
2097	I. 52	20 53 36±	74 28 49	B; R; g b M; 60″; R A from working list, no transit being procured.	12
2098	IV. 1	20 54 50·5	102 2 46	Fine planetary nebula. The disc is exactly round, and nearly of an equal light throughout; blueish white; a little haze about it: has a * 15 m n p (about 80°) dist = 3 diameters.	10
		52·0	1 53	Round; v B; equal to a * 6.7 m; the light perfectly equable, only a little dim at the edges; diameter = 300″.	9
		54·3	2 4	v B; diam 20 ... 25″; a little oval, perfectly well defined	365
		55·0	1 40	Exactly round; a very little hazy at the borders; the rest of the disc quite equable; light blue; diam 10 or 12″. [See fig 44. M. Struve has given as measures of the diameters of this nebula 25″ and 17″. From the general tenor of the foregoing obs I am disposed to think this ellipticity greater than the real.]	34
2099	I. 192	20 55 25·0	36 6 23	L; E; r; has an appearance of two nuclei or points of greatest condensation; it touches a fine double star.	211
		36·0::	6 55	L; E; 60″ l, 40″ br; r; one star is very plainly seen; it is rather wedge-shaped, pos = 225° ±. A double * is close to it. R A very doubtful.	—
2100	Nova.	20 55 27·1	103 10 11	e F; R; r; 60″	48
2101	Nova.	20 56 6·5	48 20 50	A cluster. No further description.....	210
2102	II. 203	20 56 21·8	60 46 18	p B; S; p s b M; 12″; has a * 10 m, pos 345°·0 by microm; field full of stars.	177
		23·8	46 48	p B; R; p s b M; 15″	178
2103	VIII. 57	20 59 38·5	49 11 7	A loose straggling coarse cl. Stars 10 ... 11 m, place that of 3 *s 10 m in a triangle in the closest part. Several st precede the cl, which seems to be an outlier of the second branch of the Milky Way.	183
		101·0	8 31	A poor and loose cluster; place that of a double star, h. 1613 of my fourth Catalogue.	180
2104	Nova.	21 2 11·7	75 14 19	A scattered cluster of small stars	12

Fig. 82.

Fig. 44.

No.	Synonym.	R 1830·0. h m s	N.P.D. 1830·0. ° ′ ″	Description and Remarks.	Sweep.
2105	VIII. 74	21 2 29±	39 50 24	A curious scattered cluster of triple stars; R A taken from working list.	207
2106	Nova.	21 3 49·3	56 58 6	A cluster, not very rich; irreg figure, 8′ l, 5′ br; stars 11…15 m	199
2107	Nova.	21 5 9·8	45 0 51	A star 6.7 m situated just beyond the n f edge of a L, p rich cluster, 11 .... 15 m, 20′ long, 7′ broad. Extended from n f to s p.	210
2108	Nova.	21 6 18·4	86 10 55	e F; field feebly illuminated by ☾, but I remained satisfied of its reality.	79
2109	III. 858	21 6 20·7	87 51 53	e F; R; l b M	95
		22·9	51 25	e F; R; barely visible; night exquisite	94
2110	VI. 24	21 6 34·7	48 11 8	v F; L; irreg fig; p rich; not m b M; 2 or 3 p L stars, the rest 16 .... 18 m; 5′ diam.	204
		40·9	13 3	v F cl of e S st, 15 .... 18 m; irr fig; p L; v g l b M; 4′ diam; a delicate object.	183
2111	Nova.	21 8 20·3	54 30 41	No description. A cluster	168
2112	III. 145	21 11 17·4:	64 16 47	F; R; 20″; the R A may be 2ˢ or 3ˢ out	172
2113	Nova.	21 12 43·6	99 30 3	v F; R; g b M; near a double star	86
2114	Nova.	21 14 34·8	33 7 25	A F, S, poor cluster, 8′ diam	212
2115	Nova.	21 15 16·0	39 54 40	The chief * of a coarse, poor cl	207
2116	VII. 51	21 17 5·4	44 21 8	A neat, pretty compact cluster of 50 or 60 stars 4′ diam; irreg fig; a * 13 m taken, the chief in the preceding part.	203
		7·2	20 32	A * 10 m, the preceding of a cl, 4′ in diam, and pretty rich	209
		7·6	20 28	A fine cluster of a triangular figure; the preceding * taken	210
2117	Nova.	21 17 31·5	54 13 24	A poor cluster, stars 10 m	168
2118	VII. 50	21 18 33·0	42 42 27	A double *. The chief of a poor cl	209
2119	Nova.	21 20 26·6	42 48 6	A very poor and small cluster of an oblong figure. It is followed by a loosely scattered mass of stars.	210
2120	M. 15	21 21 43·0	78 34 19	v B; v L; irreg R; g b and v s m b M. A magnificent globular cluster; comes up to a perfect blaze in the centre, like a protuberance or nipple; not the condensation of a homogeneous globe; it has straggling streams of stars, as it were, drawing to a centre. It is not *round*. Has a * 8 m, 30ˢ following in parallel.	14
		…	36 ±	Superb; very comp; irreg R; v S stars 15 m, all distinct but running together into a blaze in middle; 4′ or 5′ diam. One * 8 m n f dist 10′.	13
2121	III. 859	21 22 47·0	88 15 13	v F; S; R; has a * 14 m south. Dist from centre = 1 diam (by diagram).	295
2122	VII. 52	21 23 16·9	43 38 57	A * 10 m, the chief of a p rich, fine, L, coarse cluster. Stars 10 .... 13 m.	—
2123	Nova.	21 23 46·7	73 19 19	A coarse scattered cluster	12
2124	VI. 32	21 24: 35·7	39 10 30	A ruddy * 11 m in midst of a beautiful cluster of stars 16…18 m; 8′ diam; not very comp; ☾ troublesome.	207
		47·4	9 4	A rich fine cluster of st 11…16 m; it fills field; but the most comp part is about 6′ in extent. The middle of the cluster taken, but no particular star fixed upon. [N.B. This and the former obs disagree in the minute of R A, this giving 23, the other 24. The latter is probably right, agreeing better with my Father's determination.]	384

No.	Synonym.	R 1890·0.	N.P.D. 1890·0.	Description and Remarks.	Sweep.
		h m s	° ′ ″		
2125	M. 2	21 24 39·6	91 34 11	A fine large globular cluster; it shines out between the clouds, and I see the stars of which it consists; and the determination of its place is good, though there is not a star now to be seen with the naked eye for clouds. (See fig 88.)	81
		40·0	91 34 18	A most superb cluster; round; stars e S; 12, 13, 14 m; they are evidently globularly arranged, and not internally condensed towards the centre more than the spherical form would make them appear to be; but in the middle they blend into a blaze of light. It is like a heap of fine sand! With 9 inches aperture I can just see the stars; with 6 it is resolvable.	288
		...	35 ±	A most glorious cluster of stars 15 m compressed up to a blaze. Its most crowded part takes 6ˢ to pass the wire, but there are straggling stars, although few, of the same size as the rest. There must be thousands of them. The total light of the cl not exceeding a star 6 m, it follows that several thousand stars 15 m = 1 of 6 m.	96
2126	M. 39	21 26 7·8	42 18 52	A * 7 m, one of a large loose cluster of stars 7 .... 10 m; very coarsely scattered, and filling many fields.	209
2127	Nova.	21 27 57·8	44 45 3	The chief star (9 m) in a cluster of the 8th class. The double * No. 1660 of my fourth catalogue belongs to this cluster.	210
2128	M. 30	21 30 41·5	113 55 26	Fine cluster; irreg R, with two projections A, B, at its northern side. (See fig 90.) A is directed from the central brightness and consists of 3 or 4 bright stars 12 m; its position taken with microm = 350°·4: B originates in the preceding side of the centre, and is directed in a position 331°·7 in a line not passing through the centre: diam = 6′, stars = 12 m; fine object; has a * 9 m preceding it (2 or 3 diameters by diagram).	299
2129	Nova.	21 38 8·4	36 9 35	A small, poor, but neatly defined cluster of stars 10 ... 12 m; with appendages n p at some distance.	212
2130	VII. 40	21 38 20·3	37 5 2	A star 9.10 m of a ruby red colour in an oval annulus of small stars 4′ diam.	384
2131	IV. 75	21 39 2·2	24 40 41	A very coarse triple star involved in a nebulous atmosphere; a curious object. The neb is e F and graduates away.	221
		4·7	40 17	Three stars in a nebula. Pos of A and B = 296°·3, Δ R A = 8ˢ·0; pos of A and C = 46°·3, Δ R A = 8ˢ·0; the place is that of A.	224
2132	II. 261	21 40 20·6	68 37 4	F; R; v g l b M; 30″; r	166
		21·5	37 44	v F; irreg R; 40″; r	90
2133	Nova?	21 41 21·7	60 49 46	Strongly suspected neb, or a v F double star with nebulosity. Has a * 11 m n p.	177
2134	VII. 66	21 41 51·0	24 58 57	The chief star in the s f part of a large, pretty rich, loose cluster of st 12 ... 14 m; diam 10′; has more than one * 10.11 m in it.	221
2135	III. 452	21 45 56·7	87 51 33	F; R; p L; 40″, v g l b M	295
		57·7	51 5	p F; S; R; p s b M	95
		58·8	51 8	e F; p L; b M; a glorious night	94
2136	VIII. 67	21 48 56·7	28 11 31	One star 8 m (place taken), 4 = 10 m, 2 = 11 m, and a few smaller.	217
2137	III. 930	21 50 10·6	107 19 11	Suspected, but the state of the air is most unfavourable	37

No.	Synonym.	R 1830·0.	N.P.D. 1830·0.	Description and Remarks.	Sweep.
		h m s	° ′ ″		
2138	III. 692	21 51 52·1	104 5 16	The faintest thing imaginable	10
		...	5 41	v F; E; P D only a rude approximation	34
		...	5 53	v F; R; v g b M; r; 90″	9
2139	II. 247	21 52 25·5::	73 5 23	R; g b M to a nucleus; has a * 89° s p, dist 90 ... 100″	11
		31·2::	4 19	p B; R; g b M; 60 ... 90″. [N.B. The right ascensions in these early sweeps cannot be relied on.]	12
		34·4	4 24	B; R; p s b M; 20″; equals a * 10 m	92
2140	III. 693	21 52 46·6	111 22 2	v F; S; R; 1 b M; the first of 2	299
2141	Nova.	21 52 52·7	35 59 25	The chief * 9 m of a v L, loose clustering group which fills two fields and is pretty rich of large stars.	212
2142	II. 595	21 52 56·1:	109 43 51	e F; p L; R; the R A may err 10ˢ	285
		59·4	44 5	v F; p L; R; p g l b M; 50″	297
2143	II. 1	21 53 11·0	111 37 26	p B; p L; v m E; position = 64°·3; p s v l b M; 2′ long	299
2144	Nova.	21 53 28·6	111 17 36	v F; p L; irreg R; v g l b M; the second of two	299
2145	Nova.	21 55 14·3	80 0 0	A coarse straggling cl. Stars 9.10 m	14
2146	II. 599	21 55 52·8	49 46 8	v F; l E; S; v g l b M; 15″	183
2147	VII. 53	21 58 30·4	44 20 18	A * 10 m about the centre of a fine L rich cl; stars 9 ... 12 m; fills field.	210
		31·0	20 17	Place of * 10 m near the middle of a fine L p rich cluster; 50 stars from 10 m to 13 m counted. It fills field. Moon full.	209
2148	Nova.	21 58 35·5::	62 43 0::	e F; R; b M; ill-defined; a v F double star 45° n p 4′ dist points just to it.	103
2149	II. 207	22 0 16·9	59 29 20	B; R; 30″; g b M	199
2150	II. 897	22 0 56·7	107 28 41	No description	37
2151	III. 862	22 3 0·4	49 49 36	e F; S; E; among 3 stars, with which however it seems not connected.	183
2152	III. 931	22 4 59·5	107 54 31	v F; R; b M; 20″	37
2153	II. 606	22 5 30·0	45 29 43	A most e F nebulous appearance, which is probably only a few minute stars. No other near.	204
2154	VIII. 63	22 6 30·8	33 34 23	A * 10 m, the chief of a p compact cluster of 15 or 20 stars 10 .... 17 m. One, 11 m, is of a ruby colour.	211
		31·1	33 45	A poor cl. South of the chief * is a ruby star 10 m. (N.B. These ruby stars often occur in clusters.)	212
2155	VIII. 75	22 8 30·4	40 57 50	A double * in a very loose straggling cl which more than fills the field.	207
2156	III. 932	22 8 31·2	106 25 43	v F; R; v g b M; has * 13 m south, at a dist from edge = 1 diam by diagram.	274
2157	VI. 29	22 8 55·4	36 30 57	A Milky Way cluster. Stars 14 ... 15 m. It is more crowded than the Milky Way, so as to run up to a condensed but faint mass of light.	384
2158	III. 933	22 11 11·3::	106 38 11::	e F, but certainly seen; p L; vision v bad	37
		15·7	37 43	p F; l E; g p m b M; 20″	274
		17·2	36 57	v F; R; but hazy. In occasional glimpses p B	273
2159	Nova.	22 14 19·0	32 45 52	The chief * of a coarse p rich cluster which fills the field. Stars 10 ... 15 m.	215

No.	Synonym.	Æ 1830·0. h m s	N. P. D. 1830·0. ° ′ ″	Description and Remarks.	Sweep.
2160	II. 284	22 18 8·5:	74 43 3	F; R; g b M, to a bright point	11
		12·7:	42 59	F; irreg R; b M; near a v F double * and one large *	12
2161	Nova.	22 18 33·5	33 1 32	Large, coarse, not extremely poor, the stars scattered and 10…16 m.	215
2162	Nova.	22 19 29·1	61 45 56	v F; R; 12″….15″; among stars	177
2163	VII. 41?	22 21 10·2	38 2 35	A Milky Way straggler; a poorish cluster of stars 12….13 m	384
2164	Nova.	22 21 51·5	104 53 37	F; p L; a strong suspicion; almost sure	273
		52·2	53 8	v F; R; v g l b M; 20″; twilight commencing	274
2165	IV. 31	22 23 15·6	104 59 37	F; p L; R; v s b M to a S, F, R nucleus; diam 2′; has a ⁘ s f in pos 352°·5 by micr; dist 3′.	273
		15·7	60 23	F; E; s b M; twilight commenced	274
		16·7:	59 51	F; R; b M; 15″; by obs R A = 22ᵐ 16ˢ·7, but this is an obvious mistake.	37
		18·5	58 57	F; S; R; v s b m to a * 14 m	373
2166	Nova.	22 23 31·3	59 54 58	v F; R; v g b M; 12″; fog coming on	178
		40·3	54 16	v F; R; v l b M; 20″. Both obs are correctly reduced, and their difference in R A has probably arisen from a mistake in one or other of the moveable wires for the fixed.	177
2167	II. 476	22 25 19·5	101 13 15	v F; p L; b M; 2′	34
		20·0	13 38	p F; p L; R; g l b M; diam 4ˢ of time	86
		20·1	15 16	e F; hardly discernible	10
		21·0	14 13	F; R; v g b M; r; 2′	9
		22·1	14 12	e F; p L; R; g b M; 40″ or 50″; it precedes a double * 43ˢ·5 and is 1′ north of it.	372
2168	II. 428	22 25 31·9	85 18 18	Not v F; S; p s b M	94
		34·3	18 46	p B; S; R; p s b M	95
2169	III. 180?	22 26 14·3:	70 33 ±	No P D obtained for clouds, but found by working list; e F	90
2170	III. 237	22 28 19·9	69 15 7	p F; irreg R; v g v l b M; 15…20″	290
2171	Nova.	22 29 2·1	80 20 30	v F; R; v g l b M; 20″	305
		3·2	20 19	e F; E in parallel	15
		3·8	20 20	e F; e in parallel; 60″ l, 40″ br	13
		…	20 19	e F; l E; b M; extended in parallel	14
2172	I. 53	22 29 17·4	56 28 46	v B; p L; s m b M; E 70° n p to s f; 90″ l, 30″ br. If I. 53, the working list is 9′ out in P D.	105
		…	30 ±	B; m E; p s b M; r; 30″ l, 12″ br; has another nebula 14ˢ·5 following; pos about 55° s f, n p.	168
2173	II. 233	22 29 18·1	67 4 36	B; S; m E in pos = 163°·0 by microm; v s m b M to a * 11 m	166
		18·6	5 7	p B; S; m E; s b M; pos about 70° n p to s f; the preceding of 2.	290
2174	III. 166	22 29 31·9	56 27 9	e F; it is n f from I. 53; pos by microm = 61°·8; Δ R A = 14ˢ·5.	168
2175	II. 234	22 29 38·3	67 5 6	F; S; E nearly in parallel; v g l b M	166
		41·6	5 27	v F; m E in parallel; 60″ l; the following of two and a third suspected.	290

No.	Synonym.	R 1830·0.	N.P.D. 1830·0.	Description and Remarks.	Sweep.
		h m s	° ′ ″		
2176	Nova.	22 31 28·4	79 52 0	e F; p L; 60″ l, 30″ br; a certain obs	304
		...	.....	Viewed; e F; about a radius of the field (= 7½′) n p ζ Pegasi.	305
2177	Nova.	22 33 5·4	33 29 23	A star 9.10 m, chief of a p rich, v L, very coarse cluster	211
2178	II. 705	22 34 0·1	29 36 27	B enough to be noticed and caught in sweeping in full moonlight, with the ☾ on merid; p g b M; R; no nucleus seen.	218
2179	II. 442	22 35 41·0	91 3 18	v F; S; R; p s b M; 15″	288
		42·2:	2 55	p F; R; 25″; clouds interfered with the R A obs which may err 2ˢ or 3ˢ.	371
2180	III. 477	22 37 3·1	101 54 16	e F; R	10
		5·5	54 21	v F; p L; R; v g v l b M	373
		6·1	53 57	v F; p L; R; s b M, very dilute at borders	34
		6·9	53 7	e F; R; 20″	372
		...	53 53	F; R; 1′ diam; no other near	9
2181	II. 598	22 38 34·0	113 11 26	p B; l E; g b M; 20″	299
		35·2	11 34	p B; R; b M; 15″	293
		35·6	11 51	p F; R; v g b M; 30...40″; several small stars near	370
2182	VIII. 77	22 39 28·1	32 42 28	A L, p rich, v coarse cl of stars 9.10 m and below. (No particular ✱ taken.)	211
		72·0	48 36	A double ✱, the chief of a fine, p rich, L cluster, 10′ diam; stars 9...13 m.	214
2183	III. 216	22 41 26·4::	79 16 59	F; R; g b M; a star precedes	15
		32±	17 30	p B; R; 20″; has a ✱ 11 m near. The preceding of two neb. The ✱ by diag is 1 radius of the neb n p its edge.	304
2184	III. 217	22 41 32·9	79 12 5	p B; R; the following of two	305
		39·5::	12 5	p B; S; R; p g b M	304
2185	II. 443	22 41 52·0	92 26 43	p F; R; p s b M; 50...70″; has a ✱ n p; pos by microm = 350°·3.	288
		52·8	26 5	p B; R; s b M to a ✱ 13 m; 25″. It has a ✱ 12.13 m, 1′ north	371
2186	II. 702	22 42 37·0	111 30 26	p B; R; g b M; 20...30″	299
		38·7	30 22	p B; irr R; p g b M; 30″	293
		39·1	30 46	Not v F; l E; g b M; 60″ l, 40″ br	370
2187	II. 453	22 42 46·7	96 27 24	e F; R; v g b M; sky dull	184
		48·6	27 48	No description	186
2188	Nova.	22 43 20·2	38 43 24	A double star, the last of a poor cluster of about a dozen stars	208
2189	Nova.	22 43 39·9	89 48 24	p F; irreg R; b M; 60″; r	93
		41·6	48 31	p F; R; g b M; 30″	295
2190	VII. 43	22 47 32·3	30 4 16	A S cluster of small stars 12 m, diverging in a fan shape; a ✱ 10 m follows.	214
		39·5	5 3	A ✱ 10 m in a cluster of v S stars 15...18 m; p rich; v g b M. A ✱ 8 m is 2′ south.	213
2191	III. 745?	22 48 4·9	33 47 48	A large patch of the Milky Way, consisting of stars so small as to be quite nebulous. If this be not III. 745, I find no other.	211

No.	Synonym.	R 1830·0. h m s	N.P.D. 1830·0. ° ′ ″	Description and Remarks.	Sweep.
2192	III. 576	22 48 5·0	54 32 13	F; S; R; b M; 12″. A double ✱ s p points back somewhat n of the neb.	168
		22±	54 36 ±	e F; p L; R; a coarse double ✱ 6 m precedes a little to south. Hurried obs.	105
2193	Nova.	22 49 6·3	30 54 58	VIII class; pretty compact, poor cluster; stars 9 ... 11 m....	213
2194	III. 465	22 49 29·7::	77 47 19	e F; R; b M	15
		34·3	46 25	v F; R; 15″; has a double ✱ foll	305
		...	46 45	e F; S; R; precedes a neat D ✱ 5ᵐ	304
2195	III. 243	22 49 45·7	64 45 20	F; E in parallel; g b M; 60″ l, 30″ br	167
		...	48 ±	Viewed in place; v F; L; irreg fig; r	172
2196	Nova.	22 50 20·2	36 33 31	A large oblong cluster which fills two fields. Place that of the double star h. 3157 of my fifth Catal.	384
2197	II. 450	22 51 10·9	103 42 53	irreg R; p F; s b M almost to nucleus, r. The northern of a double neb. (See fig 73.)	9
		12·5	42 41	F; R; p s b M, rather the brighter of 2	373
2198	II. 451	22 51 11·4	103 44 23	p F; irreg R; s b M almost to nucleus, r; the southern of a double neb.	9
		12·5	44 21	F; R; p s b M	373
		...	44 26	The southern of a double nebula	10
2199	II. 251	22 51 38·5:	74 55 23	p B; L; v g b M; E pos 85° n p to s f.....	11
		39·4	56 11	No description	175
2200	II. 590	22 52 48·4	89 9 8	Hardly visible for ☾, but sure of object	108
		48·6	9 18	v F; v S; p s b M	295
2201	II. 212	22 52 51·8	60 46 10	B; L; l E; p g b M; 60″; has a stellar point in the centre ..	178
2202	III. 210	22 53 27·2	74 56 1	No description. The first of 2.....	175
2203	III. 211	22 53 36·2	74 56 38	No description. The second of 2.....	175
2204	III. 230	22 54 41·6	82 1 59	F; S; R; v s m b M; equals a ✱ 12 m with a v F wisp about it. At first seems a star.	281
2205	I. 55	22 56 24·0	78 35 19	p B; irreg R; r; I see 2 or 3 stars in it; E between 2 stars. (See fig 63.)	14
		26·0	35 30	B; m E; pos by micr = 192°·0; p g m b M; has a ✱ 12 m n p; a large ✱ s, and one or two 15.16 m in or near the middle.	304
		26·9	35 35	p B; m E, pos by micr = 11°·8 (= 191·8); 2′ l, 30″ br; between 2 small stars. Has two v S stars in it.	305
		28·8:	35 50	p F; b M; E in merid between 2 stars; 90″ l, 40″ br	13
2206	Nova.	22 57 8·7	87 22 23	v F; E; p s b M; 20″ l, 8″ br	295
2207	Nova.	22 57 58·3	56 48 46	v F; S; R; b M; 12″; has a ✱ 10 m, 5′ p in same parallel ..	168
2208	III. 558	22 59 27·3	106 32 16	e F; v L; 2 or 3′; the faintest thing imaginable; half way between two coarse double stars in same parallel.	307
2209	III. 203	23 0 36·0:	72 45 23:	e F; E like the tail of a comet; l b M	11
		36·8	44 13	v F; m E; pos 45° n f to s p; 4′ l, 1′ br	92
2210	III. 184	23 2 55·2	93 5 3	Not v F; v S; R; b M; well observed.....	96
		58·8	3 55	Not v F; R; g b and s m b M to a ✱ 15 m	371
2211	II. 2	23 2 56·3	119 28 9	F; R; b M; 30″; has a ✱ 10 m, 10° n p; 4′ distant	292

No.	Synonym.	Æ 1830·0.			N.P.D. 1830·0.			Description and Remarks.	Sweep.
		h	m	s	°	′	″		
2212	Nova.	23	3	14·3	77	59	19	e F; seems to have a * in centre	15
				15·5		59	19	e F	14
2213	VII. 44	23	4	4·0	30	21	1	A fan-shaped cluster composed of two principal lines of stars drawing to one about 2′ l; pos 248°·8 by microm.	214
				10·6		21	18	A v pretty fan-shaped cluster of p B close stars in two lines with other smaller to N. A * 10 m taken. Another 11^m dist 19^s·0; pos = 244°.	213
2214	III. 220	23	4	16·5	78	14	20	p B; p L; R; g b M; 30″	304
				16·6		14	30	p B; p L	305
				18·3::		15	0	F; R; v g l b M	13
2215	II. 229	23	5	56·4	86	25	43	F; S; R; b M; the s p of 2	95
				58·0		25	19	v F; irreg R; b M; the s p of 2; pos by microm 48°·0	302
2216	II. 230	23	6	5·4	86	23	25	v B; L; E, 10° n p to s f; 80″; the n f of 2; a * 10 m s f	95
				7·0		23	19	B; m E; pos about 5° n p to s f; 80″ long; the n f of 2, pos of the other 228°·0.	302
2217	Nova.	23	6	7·8	67	14	6	F; S; R; p s b M; 12″	166
2218	Nova.	23	6	35·7	71	56	43	The n p of 2	92
2219	Nova.	23	6	48·2	71	57	43	p B; R; 20″; the s f of 2	92
2220	II. 235	23	6	59·7	93	18	52	p B; R; a bright double * f	96
2221	Nova.	23	7	±	78	21	±	F; R; b M; place very loose; two or three more nebulæ suspected in the neighbourhood.	174
2222	III. 221	23	7	14·4	77	37	31	F; R; v g b M; 30″	175
				14·7		37	50	p B; p L; R. Has a * 16 m in the centre. The n p of 2	304
				14·7		36	49	F; R; b M; 30″; the n p of 2, the place by reference to the other	15
				16·8::		39	40::	F; R; v g b M; place very uncertain by estimation from the other.	13
2223	III. 222	23	7	19·7	77	44	19	p B; S; R; s m b M; a B * near; the s f of 2; the R A supposes a mistake in the wire.	15
				22·9		43	16	p B; R; p s b M; 20″	175
				24·0		44	10	p B; p L; R; has a * 16 m in centre. The s f of 2	304
				25·8::		44	30	e F; b M; the R A supposes a mistaken wire	13
2224	II. 467	23	7	20·0	84	14	9	B; S; R; p s b M; 15″	302
2225	III. 182	23	8	44·8	72	14	8	F	92
2226	II. 236	23	9	22±	95	34	7::	p B; S; R. R A from working list	96
2227	II. 431	23	10	5·5	98	28	44	F; R; l b M; 15″; sky not good	184
			10	9·3:		30	18	p B; R; p s b M; 15″; R A doubtful 2 or 3 seconds	186
2228	I. 104	23	10	18±	99	25	17	v F; L; m E; night unfavourable	372
2229	Nova.	23	11	19·9	82	31	9	e F; e S; sky clear	281
2230	II. 439	23	11	37·4	82	44	28	B; p L; R; p s b M	280
				39·5		43	10:	p B; R; b M; 30″. P D inaccurate	89
2231	III. 435	23	11	54·1	82	31	39	p F; R; p s b M	281
2232	II. 250	23	11	56·0	73	42	53	B; R; s b M; 60″	11
				58·8:		41	55	p B; R; b M; 25″	92

No.	Synonym.	Æ 1830·0. h m s	N.P.D. 1830·0. ° ′ ″	Description and Remarks.	Sweep.
2233	II. 440	23 12 6·7	82 42 48	B; R; pL; p s b M	280
		7·0	42 10:	p B; R; b M; 30″; P D inaccurate	89
2234	II. 441	23 13 5·3	82 2 29	A double star with some singular nebulous appendage. The stars are 14 m.	281
2235	IV. 52	23 13 20·3	29 45 1	A star 9 m with a v F nebulous atmosphere or a nebula rather excentric towards the s p side.	214
2236	II. 600	23 13 56·7	50 3 35	v F; E; v g l b M; 40″ l, 20″ br	180
		59·1	5 40	F; L; m E from a bright to a faint star; v l b M; 2½′ l, 20″ br. See fig. 60.	183
2237	Nova.	23 16 21·5 ::	75 39 23	F; R; g b M; 40 . . . 60″	11
		. . .	38 45	e F; R; g b M; 30″; appears as M. 71 does in the 7-feet reflector with the double eye-piece.	1
2238	M. 52	23 16 43·9	29 20 12	A ruddy star 9 m in the p part of a p rich irreg cl of stars 13 m, all separate, 6′ diam; a v little more comp in the s f part.	218
2239	III. 212	23 17 22·4	76 43 26	v F; S; R; p s b M; 15″	175
2240	Nova.	23 17 24·2	63 54 0	F; v S; p s m b M; 6″; almost stellar; a star 10 m p; dist 1′ in parallel.	172
2241	IV. 18	23 17 42·1	48 24 24	A fine Planetary Nebula. Diameter 12″; with 240 beautifully defined, light, rather mottled, and the edges the least in the world unshaped. It is not nebulous, but looks as if it had a double outline, or like a star a little out of focus. A perfect circle. Has a star near; pos 68°·1, well measured over the centre of the nebula. See fig 45.	183
		43·2	23 33	v B; R; blueish white; 8 or 10″ diam. It has no haze at the edges, but ? if it be not enveloped in an e F nebulosity (perhaps arising from glare) and also the star 13 m whose pos is 61·9 and Δ R A = 4ˢ·0. The light is a very little mottled and not absolutely planetary. It is = a ✱ 7 m. (N.B. These *satellites* of planetary nebulæ ought to be especially attended to.)	180
		44·0	23 53	Diameter in R A = 2ˢ·0 of time. The attendant star is double A = 12 m; B = 13 m, pos of A = 58°·5; Δ R A from centre = 4ˢ·0. The nebula is not perfectly round; light equal, but a very little hazy at the edges.	204
		44·3	23 40	Exactly R; 2ˢ·5 of time = diam in R A. Has a ✱ 13 m pos 69°·0; dist 30″; the light of the disc is perfectly equable, and equals a star 8 m.	189
		46·2	23 40	Exactly R; = a ✱ 8 m; a ✱ 13 m n f; pos = 65°·6 by microm; dist = 30″. [N.B. The great discordance in the measured positions of the satellite-star seems to arise from the star being double, and taken for a single one. Whenever this occurs, it is a source of error, and should be most carefully guarded against in all future observations of this interesting object.]	190
2242	III. 226	23 18 41·3	78 28 39	p B; R; v s b M, almost to a star	15
		44·9	28 0	p B; S; v l E; b M; has a ✱ 8 m p	305
		45·0	28 10	p B; S; R; a star 10 m precedes in parallel near the neb	304
		45·8	29 0	p B; S; R; 20″; m b M, with a hazy border. Approaching to a stellar, or a planetary character. [A mistake in the wire presumed in the transit observation.]	13

Fig. 45.

No.	Synonym.	R. 1850·0. h m s	N.P.D. 1850·0. ° ′ ″	Description and Remarks.	Sweep.
2243	Nova.	23 19 18·6	82 9 4	F; R; g b M; 30″. The p of 2	281
2244	Nova.	23 19 28·6	82 9 49	v; F; R; g b M; 20″; the f of 2	281
2245	II. 226	23 19 57·8	68 30 37	F; v R; p L; 1 b M; very symmetrically situated in the southern part of a lozenge of 4 stars, on the longer diagonal, forming an elegant object. See fig 85.	91
		59·1	30 28	v F; R; v g b M. Occupies the southern half of a lozenge of four stars, its centre being just upon the longer diagonal.	166
2246	III. 860	23 20 21 ±	58 35 ±	S; R; query if not stars; R A by working list. P D rough.	100
2247	II. 242	23 20 21·2	73 37 53	e F; S; it is a v F neb of third class	92
		22·5 :	38 3	v F; R; g b M; 20 .... 30″; near a double *	11
2248	III. 426	23 21 50·1	87 2 3	e F; L; 60 .... 90″	295
		...	2 ±	e F; L; 90 .... 2′	302
2249	VIII. 69	23 22 3·7	41 49 2	A bright coarse cluster 7′ diam; seen in full ☾. Place of the chief * = 7 m; about a dozen 9 .... 11 m, and many 12 .... 14 m	209
		3·9	47 54	A poor scattered cluster. Place of a * 8.9 m in preceding part. Full ☾ on merid; so that I could not see the small stars.	208
		...	49 20	A * 6 m in the middle of a cluster of about 50 stars coarse and straggling.	207
2250	III. 213	23 23 50·0	75 5 31	e F; p L; forms a triangle with 2 st 10 m, near it	175
2251	Nova.	23 26 13·5 ::	74 52 23	v F; v S; g b M; 10″; has a * 1′ dist n f	11
2252	Nova.	23 26 21·2	86 2 18	e F; hardly perceptible; a * 12 m precedes	94
		21·3	2 28	e F. The s p of 2	95
2253	Nova.	23 26 30·3	85 58 58	v F, but brighter than the preceding	95
2254	III. 579	23 26 34·6	46 37 28	e F; follows a * 9.10 m. (? if not an e F double *.)	204
		36·7	37 50	e F; R; 20″; has a * 11 m, 45° n p; dist 25″	190
2255	VIII. 62	23 26 58·0	18 1 12	A * 8.9 m, the chief of a scattered cluster of 30 .... 50 stars, 10 .... 15 m. It more than fills the field.	378
		62·5	1 47	A poor and coarse cluster of large and small stars. The largest (= 9 m) taken.	228
		...	1 ±	A star 8 or 8.9 m, the chief of a poor and diffused cluster of small stars.	229
2256	II. 244	23 27 4·4	75 38 31	p F; R; p s b M; 15″	175
		...	37 ±	v F; R; g m b M; 20″; r; like a blotted star	1
2257	Nova.	23 27 30·6	88 46 48	p B; S; R; p s b M; in field with 16 Piscium; a star 12 m near, s p; (dist = 1 diameter of neb by diagram).	295
2258	Nova.	23 27 47·8	90 38 40	Not e F; p L; 1 E; g b M; has a * 10 m exactly south, dist 2′	371
2259	III. 146	23 29 58·4	63 55 32	p F; R; b M; 20″	172
2260	II. 432	23 30 0·6	97 27 48	v F; L; R; v g b M; 60″	186
		2·5	27 32	p B; p L; p m E; irreg fig. Sky not quite clear	184
		5·0	27 9	No description	185
2261	I. 110	23 30 7·5	103 53 56	e F; L; m E; sky quite clear	373
		9·4	53 53	Irreg R; g b M; 2′ diam; r. I certainly see one star near the middle.	9

No.	Synonym.	Æ 1830·0.	N.P.D. 1830·0.	Description and Remarks.	Sweep.
		h m s	° ′ ″		
2262	I. 111	23 31 5·1	103 14 26	p B; R; p g m b M; 40″	373
		6·2	13 53	p B; R; v s m b M	9
2263	Nova.	23 33 47·1	64 42 12	v F; a star 14 m with a nebulous brush extended towards the star, and on its s p side; position from the star by diagram = 250° or 260°. This disagrees with my Father's description of II. 208, which is said to be s f a star, but this may be a mistake for s p; but then also the R A disagrees 2ᵐ and the P D 6′. It can hardly, therefore, be the same object.	172
2264	II. 255	23 35 36·8	80 10 9	B; R; a B ✱ f	15
		37·1	10 30	B; R; p s b M; 25″; a ✱ f	305
		37·2	11 10	F; R; s b M; 20″; has a ✱ f	89
		45·3::	10 30	B; R; g m b M; 60″; has a small ✱ one diameter following. [N.B. The R A is good for nothing, as are all those in the early sweeps before the chronometer was used.]	13
		...	9 44	R; s m b M almost to a nucleus; has a ✱ 1′ dist, 20° n f	14
2265	II. 256	23 35 41·9	81 0 38	p B; R; s b M; 20″; r	280
		...	0 5	p B; R; p s b M; 15″; has a ✱ 15 m, dist 1′; pos = 153°·8 by microm.	305
		...	0 15::	F; S; R; b M	89
2266	Nova.	23 37 3·4	21 11 30	About a ✱ 8 m is a very extensive space which I am certain is affected with nebulosity.	223
2267	III. 427	23 37 53·2	87 8 53	Not v F; L; R; 40 or 50″ diam	295
		57·4	8 26	Not e F; p L; R; 1 b M	94
		...	8 ..	p B; L; near 2 B stars 10 and 11 m	95
2268	II. 213	23 38 32·0	61 27 42	p F; L; v g b M; 70″; r	177
2269	III. 437	23 39 18·2	84 4 32	F; S; R; g b M; 12 ... 15″	300
		...	5 ±	p F; S; R; 15″	302
2270	Nova.	23 40 3·4	86 46 2	v F; p L; R; v g l b M; 40″; a ✱ 13 m, 1′ n	300
		...	46 14	v F; L; R; has a ✱ 13 m north	302
2271	III. 854	23 40 34·3	59 57 45	p B; p s b M; 12″; query if not a F double ✱ with neb	178
		36·6	57 41	v S; r; I am sure I see 2 stars; a suspicious object, *possibly* (not very probably) a nebulous D ✱.	177
		37·1	58 3	B; v S; query if not 3 small stars close together	100
		37·6	57 55	B; S; R; perhaps a ✱ or two in it. [N.B. The obs makes the P D 59° 52′ 55″, but there is an obvious mistake of 5′ in the reading off of the Index.]	102
		40·2	57 21	Query if not 3 or 4 stars and nebulosity	104
2272	VII. 55	23 41 39·3	22 55 50	a v L, v coarse, rather poor clust of ✱s 11 ... 15 m. The most comp part taken.	223
2273	Nova.	23 42 21·4	63 47 56	v F; S; irreg fig; appears by glimpses to contain a v F double ✱, but it *is* a nebula.	172
2274	II. 230	23 42 22·6	70 46 20	p B; R; b M; 25″	91
		26·5	48 35	p B; S; R; b M; the n p of two	92
2275	II. 231	23 42 43·6	70 48 20	p B; E; b M; has a v S almost stellar neb about 45° s p dist 40″	91
		48·0	50 15	p B; E; b M; has a smaller neb, 60° s p, 35″ dist. (See fig.)	92

No.	Synonym.	R 1830·0.	N.P.D. 1830·0.	Description and Remarks.	Sweep.
		h m s	° ′ ″		
2276	Nova.	23 43 6·5::	74 41 23	A cluster of scattered stars 10 m	11
2277	II. 851	23 43 32·6	59 40 20	The faintest conceivable	102
		36·2	41 ±	e F; s p a ✱ (by diagram ✱ 70° n f, dist 1 diam of neb from edge).	104
		...	42 ±	e F; R; near a ✱	178
2278	III. 231	23 44 39·3	83 4 9	F; R; b M	281
		39·9	4 3	p B; R; p s b M; 20″	280
2279	III. 232	23 44 46·9	83 3 53	p B; R; p s b M; 20″	280
		47·3	3 49	p F; R; p s b M; the brightest of 3	281
2280	Nova.	23 45 6·3	83 4 19	F; S; R; the faintest of 3	281
2281	III. 233	23 45 13·0	82 58 4	p B; p L; R	281
		13·6	58 18	p B; p L; g b M; 40″	280
2282	II. 468	23 46 37·5	85 1 34	B; S; R; p s m b M; among three stars	300
		37·5	1 44	p B; S; l E; p s b M; among three stars	302
		38·0	2 18	p B; R; b M; r; a ✱ 7 m precedes 30ª ±	95
		39·5	2 18	p B; R; b M	94
2283	Nova.	23 48 12·4	29 33 44	v S and close cluster. One ✱ 10 m with a great many very minute stars close to it.	216
		14·6	32 52	A p rich, S, condensed cl. One ✱ 10 m, the rest 13 m	219
2284	VI. 30	23 48 28·7	34 13 48	A most superb cluster, which fills the field and is full of stars; g b M; but no condensation to a nucleus; st 11 . . . 18 m. The place is that of a double ✱.	211
2285	VII. 56	23 48 31·3	29 43 52	A double ✱ in the p part of a pretty rich cluster; diam 4′; st 12 . . . 13 m; the f part most comp.	219
2286	Nova.	23 49 15·5	80 10 20	v F; v S. Query if not a star	305
2287	Nova.	23 50 4·3	30 55 43	A star 7 m, the chief of a v L coarse scattered but poor cl which fills the field. Stars 10 m.	213
2288	III. 466	23 50 15±	80 12 55	e F; irreg fig; p L; 40″	305
2289	III. 867	23 50 18·2	87 18 43	e F; not v S	95
2290	II. 232	23 50 45·7	70 10 15	p B; S; R; b M; has a ✱ 10 m 60° sp, dist 65″	91
2291	II. 10	23 50 56·2	76 8 26	F; S; E; irreg fig; 18″	175
2292	Nova.	23 51 46·8	40 13 40	A double ✱ in a tolerable cluster in which is one star 9 m	207
2293	Nova.	23 52 17·5	84 42 9	v F; S; R; p s b M	302
2294	III. 855	23 52 42·7	59 31 30	e F; S; R; s b M; double; the s p of 2	178
		42·8	30 27	e F; very little more than a suspicion, and could not find the object again. [N.B. A diagram made at the time represents the two nebulæ in their right position; therefore no doubt but the wire of the transit was mistaken,]	114
		...	30 31	e F; seen by glimpses in a fog	104
2295	III. 856	23 52 44·3	59 29 ±	e F; a companion to III. 855; v doubtful.	114
		45·5	29 57	e F; b M; like a blurred star	106
		46·2	31 10	e F; S; R; s b M	178

No.	Synonym.	Æ 1830·0. h m s	N.P.D. 1830·0. ° ′ ″	Description and Remarks.	Sweep.
2296	H. MS.	23 53 37·4	77 58 36	e F; follows 2 st which point a little s of it. It is called a suspected nebula by my Father in his Sweeps.	174
		39·3	58 31	"Suspected nebula." Verified; a ✱ 11 m p to n, and another v S, point a little south of it.	175
		...	57 ±	"Suspected nebula." Verified, being found in the middle of the field by setting the telescope on the place per working list; but it is so nearly a star as to be easily mistaken for the third ✱ of a triangle.	15
2297	II. 240	23 54 32·5	74 47 33	B; L; irreg R; v g b M; 2′ or 3′ diam; no nucleus	11
2298	III. 436	23 55 ±	83 35 18	v F; R	280
2299	Nova.	23 55 7·8	83 27 45	v F; p L; R; g b M	281
2300	II. 227	23 55 16·7	70 10 5	p B; m E; l b M; 2′ l, 20″ br; pos 45° n f to s p by diagram.	91
2301	Nova.	23 55 47·5	85 44 40	B; S; m E; v s m b M to a ✱; 12″ l, has a ✱ p	300
		...	.....	Viewed; p F; E; follows a s ✱; the first and southern of 3 in a line.	302
2302	Nova.	23 56 1·1	22 16 20	The central part of what I am positive is an enormously L, but e F neb of a round figure, though I cannot trace its limits. The night exquisite. I swept often across it to be sure, but always recurred to the same place. No doubt but can never be seen but in the best state of the air and sky. Diam 10′ ±.	223
2303	Nova.	23 56 23·5	84 1 44	Not v F; S; R; 12″; a ✱ 9 m n p	302
2304	Nova.	23 56 24·0	85 44 14	v F; S; g b M	302
2305	VIII. 29	23 56 29·8	111 39 39	A triangular group of about a dozen stars	293
2306	Nova.	23 56 45·5	85 43 49	v F; S; R; s b M; has a ✱ n f	302
1	III. 868	0 0 2·0	86 19 35	&c. &c.	&c.

ERRATA AND ADDENDA.

Page 361, line 9, ... *for* 2500 *read* 2300
—— 361 —— 10 .... *for* 2000 *read* 1800
—— 388 Obs. 536 .... *for* II. 880 *read* II. 280
—— 379 —— 344 .... *for* P D 52 50 56 *read* 53 10 56.

Omitted Nebula.—R.A. $13^h\ 56^m\ 23^s{\cdot}6$; P D 33° 21′ 50″; v F; Sweep 546.

APPENDIX.

The manner in which the observations, whose results are above stated, have been performed, that is to say, the method and order in which the business of a sweep is conducted, having been stated at large in my catalogues of double stars, it will not be necessary to recapitulate the particulars here; but it would not be right for me to lay before the Royal Society the present collection of reduced observations unaccompanied by some explanation of the manner in which the reductions have been executed, and how the numbers here set down as the mean right ascensions and north polar distances of objects for the epoch 1830, are concluded from the numbers registered at the moment of observation, especially since the method actually pursued for this purpose is materially different from that taken to reduce my earlier catalogues of double stars, being at once much more exact, and far less troublesome. This change has of course involved the necessity of a recalculation of all the sweeps which had been reduced on the original plan; and although this has proved a work of considerable labour, the advantage of the adoption of a uniform system throughout the reductions is more than an equivalent for the time and trouble it has cost—not to mention the detection of several errors in particular cases, and the satisfaction of a general verification of the great body of the former computations.

Every complete observation registered in the sweeping books contains the following particulars: 1st. The time, shown by a chronometer (of unknown error and rate), when the object passed one or other of the vertical wires of the eye-piece, or finally left the field, after which, though it might be recovered, and viewed and described at leisure, by withdrawing the tube from its bearing against the ladder, yet no further determination of time was practicable, other than a very rude one, by taking the transit of some small star, on the same parallel, and then temporarily fixing the tube in a new position, remote from the ladder, and noting the difference of right ascension between that star and the object, by their transits afresh across the wires so displaced.

2ndly. The wire across which the transit was observed is noted in the next place, and the first step in the process of reduction consists in applying to the

observed times of transit a reduction to the first wire, when not directly observed, founded on a knowledge of the interval between the wires and the extent of the range of the field of view, as also of the approximate polar distance of the object.

3rdly. The third datum given by observation is the reading off of the brass sector attached to the end of the tube, by the lateral microscope. The sector is graduated to degrees and minutes, and the seconds are estimated, which is easy, as each minute is nearly a tenth of an inch in length. Though I have no reason to apprehend any error in the graduations, or in the values of the degrees, minutes, &c., into which the arc of this sector is supposed to be divided, both are regarded as unknown elements, whose values, if necessary, might be investigated, but into which, by reason of the system adopted, there is no occasion to inquire, further than to be satisfied that their errors are of an order so small as not to bring into question the *identity* of an object.

These are the data furnished by observation for every object in a complete sweep; and I shall now explain how from these data, compared with the mean places of all those known objects which are to be found in authentic catalogues brought up to a given epoch, and which occur in a sweep, the mean places of all the *unknown* ones for the same epoch may be obtained, with the greatest degree of accuracy of which the system of observing is susceptible,—without the necessity of taking into direct consideration any uranographical or instrumental correction whatever,—and that in a manner which, as will appear, carries with it a moral certainty of eliminating (so far as they can be eliminated by any process) whatever errors may have been committed in the observations of the zero stars. In fact, if we consider all the corrections which we can possibly have occasion to apply to observations of this kind, whether arising from the uranographical reductions, (viz. precession, aberration, nutation and refraction,) or from instrumental mis-adjustment, such as extrameridional situation of the plane of the sweep, or its deviation from a vertical; error and rate of the chronometer; error of evaluation of the divisions of the sector, &c.; or, lastly, even from instability of the instrument itself, due to hygrometrical or pyrometrical causes, whose operation, though very irregular, is still to a certain extent gradual; we shall find that they are all functions of two quantities, —the time elapsed since a given epoch, or, which comes to the same thing, the

sidereal time at the moment of observation; and the inclination to the horizon of the line of collimation, or, which comes to the same, the polar distance of the object. Hence it follows that in all cases the mean R. A. of an object observed must necessarily be derived from the observed chronometer reading, (reduced to the first wire,) by adding to that reading a reduction (R) which is some certain function of these two quantities, and that the mean polar distances, also reduced to the same fixed epoch, will in like manner be had from the reading of the index arc or lateral sector, by adding thereto another reduction (r), which is also a function of the same quantities. We have therefore, if we call α and ϖ the mean R. A. and polar distance of any object, t the time (by chronometer) of its transit over the first wire, and i the reading of index arc, two equations of this form:

$$\alpha = t + \text{funct.}\,(\alpha, \varpi)$$
$$\varpi = i + \text{funct.}\,(\alpha, \varpi).$$

This form, however, is unsuitable to our purpose, the quantities α and ϖ being themselves the object of inquiry; but it is easy to give the equations a more available form, if we consider, 1st, that α and ϖ are never materially different, the former from t, the latter from $p + i$, where p is the polar distance corresponding to $i = o$; and 2ndly, that we intend to have no concern at all with the *analytical form* of the functions involved, which, so far as our purpose goes, may be regarded as unknown or arbitrary. Denoting then by F and f, other forms of functions equally unknown with the former, we are at liberty to suppose our equations transformed as follows:

$$\alpha = t + \mathrm{F}\,(t, i)$$
$$\varpi = i + f\,(t, i)$$

Our attention must now be directed *not* to discover *à priori*, by theory, the analytical forms of the functions F, f; *but*, *à posteriori*, from observation, to tabulate their values, or, in other words, to reduce their calculation to a simple process of interpolation between their observed values as concluded from the zero stars. To this end we must put the above equations under the form

$$\mathrm{F}\,(t, i) = \alpha - t$$
$$f\,(t, i) = \varpi - i$$

and putting $F(t, i) = R$ and $f(t, i) = r$, we must first ascertain the values of R, r from each of the zero stars observed, with the corresponding values of t and i given by observation, and then tabulate them by interpolation, for all the other values within the limits of the sweep.

With respect to the first of these operations it is very easy. For in the case of a zero star, α and ϖ are given by the standard catalogue, brought up to the given epoch if required, and t and i are the actual readings off of the chronometer and index arc, the former being merely reduced to the first wire, by an appropriate table, when that wire is not observed. The problem then is reduced to this,—given the values R, R′, R″, and r, r', r'', &c., of two functions of t and i, of whose analytical form we are ignorant, to interpolate these functions, and tabulate their values for every value of t and i within certain limits. The principle on which this problem may be easiest and most generally resolved, as well as with the highest degree of probability which the case admits, is an extension of the method I have used for interpolating the angles of position of double stars. We may regard R and r as the third or vertical coordinates of two curved surfaces, of which t and i are respectively the first and second or horizontal coordinates. Having, therefore, obtained a number of corresponding values of the three coordinates, we have given so many points in each curve surface, or rather which *should* lie in such surface were all the observations free from error. Since that, however, is not the case, the surface, such as it theoretically ought to be, did we know its true form, will not pass *through* but *among* the points in question; and it must be our care so to describe it as to deviate as little as possible from them while yet preserving a seemly and moderate flexure in itself—at least if we have no reason to believe that jumps exist in the instrumental errors.

A graphical process which should require us to describe a curve surface through or among given points in space, would be difficult, but fortunately in the case before us the difficulty may be evaded. For the limits of a sweep in polar distance being only three degrees, the amount of flexure of either of our curve surfaces in the direction of the coordinate i will of necessity be trifling, and may be disregarded. The surface therefore will be one of a cylindroidal nature, in which the ordinate is of the form funct. (t) + funct. (i), so that if

we denote by A, B, and a, b, such functions of these respective variables, we shall have

$$R = A + B$$
$$r = a + b$$

where A, a, are functions of t alone, and B, b, of i alone. Thus the interpolation of the functions R, r, is reduced to that of the functions A, B, a, b, each of which involving only one independent variable, the precepts given in my paper above alluded to, apply immediately to its interpolation, and enable us to tabulate its value with the greatest readiness.

The process which I have used throughout the reduction of the sweeps has been grounded on these principles, and may be thus summarily described.

1st. From the registered chronometer and index reading, compared with the standard catalogue adopted, deduce the reductions, in R. A. and N. P. D. of all the known stars which occur in the sweep, or the zero stars, as I have called them. By the reductions, I mean the quantities in time or in space which must be applied to the observed chronometer or index reading to produce the catalogued R. A. or N. P. D. for the epochs. These are the quantities R, R′ and r, r', &c.

2ndly. Take a piece of paper, divided into squares, either ruled or printed, of which every tenth line in both directions should be stronger than the rest. On this, choosing one direction (suppose the horizontal) for measuring off the values of the independent variable t, let the other (the vertical) be devoted to measuring off those of the function A corresponding to those values of t: and in this way lay down a series of points on the paper, having R, R′, &c., for their ordinates and the values of t corresponding, for their abscissas.

Through, or among these points, so as to make the least deviations consistent with a gentle and moderate curvature, or, if possible, with a rectilinear form, describe a curve, which may be called *the reducing curve in right ascension, for time*, and then read off the values of its ordinate R, which correspond, not to the *observed values* of t, but to a regular arithmetical or tabular progression of this quantity; for instance, to every tenth, or twentieth, or thirtieth minute, according to the rapidity of its variation. Lastly, enter these readings off of the interpolating curve in a table, which will therefore express the values of the

unknown function A, and may accordingly be used as a table of reductions in R. A. for that part of the reduction which depends on the time.

3rdly. Suppose A, A′, A″, &c., to be the values of A taken from this table corresponding to the values t, t', t'', &c., of the time, at the moments of observation of the zero stars; then, since $R = A + B$, we have $B = R - A$, and similarly $B' = R' - A'$, and so on. Thus, then, we get a set of values of B, B′, B″, &c.; and these being in like manner laid down on a paper of engraved squares, and an interpolating curve drawn, read off, and tabulated as in the case of A, we get a table of values of B to be used for that part of the reduction in R. A. which depends on the index arc.

These tables once constructed, we may apply them immediately to the reduction of all the observations of unknown objects in R. A. which were made on the first wire. But for those made on the second, or at leaving the field, a further correction will be required, viz. the interval between the wires, to be applied negatively to the observed chronometer reading. This correction is of the form $c.\ cosec\ \varpi$, or $c.\ cosec\ (p + i)$, where p is the polar distance of the *top* or *zero* of the sweep. By numerous observations made for the purpose, I have determined the value of c in my eye-piece as follows:

for the second wire, $c = 31^s{\cdot}09$;

for the final exit from the field, $c = 58^s{\cdot}69$.

In order, however, to avoid the trouble of making this subtraction, as a separate operation, for all the unknown objects which happen to have been observed under these circumstances, it is preferable to construct three independent tables of B (with which this correction, depending on i, unites itself,) to be used for observations made on the first or second wire, or at the exit from the field, which we shall denote by B^1, B^2, B^3.

To reduce the index readings to polar distances, for the adopted epoch, a process exactly similar must be used for determining a and b. A table of a being first constructed, the equation $b = r - a$ gives us the means of interpolating and tabulating the values of b. In this case, however, there is no occasion to form tables for the other wires, the bisection of the object by the horizontal wire being alike in all parts of its passage through the field, except within a degree or two of the pole.

To reduce a sweep, then, in the most general case, we require six tables, viz.

two for the values of A, *a*, whose argument is the registered time, per chronometer, and four for B^1, B^2, B^3, and *b*, having the index reading for their argument. The construction of these tables in the manner described, and their application when constructed, is attended with very little difficulty, when once the computer is accustomed to the construction and reading off of the interpolating curves. In most cases, however, the value of A is so nearly constant, that its variation (in such observations as these) may be neglected: whenever this is the case, the table for interpolating A may be suppressed, and its constant value simply added to those of B^1, B^2, B^3, which are always required. It is therefore advisable universally to regard B^1, B^2, B^3, as containing the constant part of A, by which procedure all occasion of mistake arising from change of method is taken away. Most usually also the value of B^1, so increased by the constant part of A, is the same throughout the limits of the sweep. When this is not the case, it is ordinarily owing either to extrameridional situation of the telescope, or to rapid hygrometrical changes, or lastly, to wind. But with its causes we have no concern, further than to endeavour to reduce its amount when inconveniently great, by a motion of the instrument in azimuth.

The values of *a* are liable, as I have found by experience, to considerable fluctuations, and that in very variable degrees at different epochs of the observations. Hygrometrical changes have some influence: but by far the worst, and most intractable part of these fluctuations appears to have taken its rise from the shifting of the line of collimation, owing to the mirror taking a new bearing in its cell. I regret that I did not earlier perceive this cause of error. It has only recently occurred to me, and the remedy almost at the same instant suggested itself in a simple, and what I trust will hereafter prove an effectual application of the collimating principle of Rittenhouse and Kater. It consists in attaching to the *inside* of the wooden tube of the reflector a small achromatic telescope, having its object-glass turned towards the speculum, and its eye-end projecting at right angles to the axis of the tube through an aperture in the side, the cone of rays being deflected outwards at a right angle by a small mirror 45° inclined to its axis. In the focus of the object-glass, (thus rectangularly deflected,) is fixed a cross of fine spider-lines, strongly illuminated by a lamp (capable of being shut off when not wanted), which also serves to illumi-

nate the field. The cross is so situated that its image, seen in the telescope as an object infinitely distant, (according to the principle of the collimator,) makes with all its arms, angles of 45° with the horizontal and vertical wires of the sweeping eye-piece. In the beginning of a sweep, the intersections of both crosses are brought to exact coincidence (by a method presently to be explained); and it is evident that if in the progress of the sweep the slightest shifting of the mirror in its cell should produce a motion of the line of collimation, it cannot fail to be detected by the apparent recess of the two crosses from their original common intersection. A relative motion, to the amount of two seconds of space, either laterally or vertically, cannot possibly escape detection, as I have convinced myself by many trials; and so satisfactory has this mode of overcoming the difficulty in question proved, that I have no hesitation in saying that the only obstacle to the use of large reflectors for the nicer purposes of exact theoretical astronomy, (viz. the error caused by the shifting of the mirrors in their cells, by reason of their great weight, and the danger of securing them by strong pressure,) has ceased to exist*. It is not, however, sufficient to have the means of readily detecting error, without possessing that of correcting it with equal readiness, or at least measuring its amount. A very simple and effectual contrivance accomplishes this. The two adjusting screws by which the mirror case is supported against the bottom of the tube are terminated, outside of the latter, by large disks or wheels of wood about six inches in diameter, grooved at their edges. Round these, re-entering cords are conducted over pulleys, to a convenient point within reach at the mouth of the tube, forming a kind of reins, which hang loose when not in use, but by tightening or drawing one or other of them, any motion, however large or

* My first collimator consisted of a small object-glass, by Fraunhofer, of about one inch and a half in diameter, and twelve inches focus. When applied to the twenty-feet reflector, as described in the text, it formed an admirable microscope with its full aperture,—an extraordinary proof of the perfection of its construction, this being doubtless the severest test to which an achromatic object-glass can be possibly subjected. The most beautiful object I can remember to have seen in telescopes was Jupiter entering, perfectly defined, and with all the appearance of a real globe, into the image of a small glass globule, placed in the focus of the collimating telescope. It seemed like the mutual penetration of two solids, or rather two essences of different natures, the one bright and ethereal, the other dark and adamantine. This most exquisite specimen of workmanship was destroyed by an accident. That with which I have been forced, temporarily, to replace it, bears no comparison with the original.

minute, may be given to the line of collimation at pleasure. By the aid of this mechanism, the perfect adjustment of the line of collimation (to the full extent of the optical powers of the instrument,) is performed in an instant, and may, if we please, be repeated at every observation, being attended with no trouble. Nay, the line of collimation may be purposely deranged to any extent, and immediately corrected. So that by graduating the grooved disks, and adopting an index to each, a very complete distance and position micrometer for the measurement of double stars might be formed, in which, if necessary, two lucid points might imitate the two stars to be compared.

To return, however, from this digression, and to illustrate by an example what is here said of the method of sweeping, we may take that of sweep 384, in which the zero stars run as follow:

No.	Name of Star.	Observed Chronometer.	Wire.	Observed Index.
		h m s		° ′ ″
9	Piazzi, xxi. 383 ..	21 57 5·0	1	1 5 30
13	3 Lacertæ	22 18 23·5	1	0 25 0
22	P. xxii. 276	22 53 21·0	1	0 25 30
29	P. xxiii. 73.....	23 17 25·0	1	2 7 45
31	P. 0. 70.....	0 46 22·0	2	0 47 35
41	P. i. 130.....	1 30? 57·0	2	2 1 30
49	4 Persei	1 52 42·5	1	2 40 50
60	P. ii. 115	2 26 44·5	1	0 14 30
65	γ Persei	2 54 9·5	1	1 51 15
79	P. iv. 7	4 5 8·5	1	2 12 0
83	1 Camelop.....	4 21 8·5::	2	2 32 40
84	2 Camelop.....	4 28 9·0	1	2 8 0

By comparing the observations with Piazzi's catalogue brought up to 1830·0, and with that of the Astronomical Society for the same epoch, we get the following values of R, r.

No.	R.	r.
	m s	
9	−1 27·8	−39 1 6
13	−1 31·0	−39 2 15
22	−1 30·5	−39 1 53
29	−1 35·7	−39 1 49
31	−1 30·9	−39 1 44
41	−1 36·4	−39 1 22
49	−1 41·3	−39 1 9
60	−1 34·9	−39 1 43
65	−1 37·8	−39 1 16
79	−1 39·1	−39 1 25
83	−1 40·5	−39 0 48
84	−1 38·2	−39 0 17

Constructing now an interpolating curve to pass among a series of points laid down from the chronometer readings taken as abscissæ, and the values of R as ordinates, we get the following Table of A, by inspection of the course of the curve, as read off upon the squares of the interpolating chart.

$t =$	A =	$t =$	A =
h m	m s	h m	m s
21 0	−1 27·5	1 0	−1 35·3
22 0	−1 29·7	2 0	−1 36·8
23 0	−1 31·8	3 0	−1 38·0
0 0	−1 33·6	4 0	−1 39·0
1 0	−1 35·3	5 0	−1 39·8

Taking out now from this Table the values of A corresponding to the times of observation, and subtracting them from those of R, we find the following for the interpolated residues or values of $B^{(1)}$.

No.	R. A.	No.	R. A.
	m s		m s
9	+0 1·9	49	−0 4·7
13	−0 0·6	60	+0 2·4
22	+0 0·8	65	0 0·0
29	−0 3·3	79	0 0·0
31	+0 3·8	83	−0 1·1
41	−0 0·3	84	+0 1·2

Laying these down in like manner on a divided chart, we get the interpolated values of $B^{(1)}$ as in the following Table, beside which are also annexed those of $B^{(2)}$ and $B^{(3)}$, obtained by adding to $B^{(1)}$ the corresponding values of $-31^s.09 \cdot \operatorname{cosec}(39° - i)$, and $-58^s.69 \cdot \operatorname{cosec}(39° - i)$; $39° - i$ being the approximate polar distance of any object in the sweep in lieu of $39° + i$, because the telescope is directed between the zenith and pole, where i is taken negatively.

$i =$	$B^{(1)}$ for 1st Wire.	$B^{(2)}$ for 2nd Wire.	$B^{(3)}$ for leaving Field.
° ′	m s	m s	m s
0 0	+0 3·1	−0 46·3	−1 30·2
20	+0 2·5	47·3	31·6
40	+0 1·8	48·3	32·9
1 0	+0 1·2	−0 49·3	−1 34·2
20	+0 0·5	50·3	35·6
40	−0 0·2	51·4	37·0
2 0	−0 0·8	−0 52·5	−1 38·3
20	−0 1·4	53·5	39·7
40	−0 2·1	54·5	41·1
3 0	−0 2·7	−0 55·6	−1 42·6

A process exactly similar being gone through for a and b, we find $b = 0$, and for a, the following Table.

$t =$	$a =$	$t =$	$a =$
h m	° ′ ″	h m	° ′ ″
21 0	39 2 8	1 0	39 1 34
22 0	1 59	2 0	1 24
23 0	1 51	3 0	1 10
0 0	1 43	4 0	0 55
1 0	39 1 34	5 0	39 0 36

These Tables constructed, all we have to do to reduce the whole series of objects comprised in the sweep (89 in number), is to take out from them, by proportional parts, the quantities corresponding to the registered time and index, and apply them with their proper signs. Thus, for example, the star Σ. 446 in the cluster VIII. 80, which is No. 308 of the general series in this paper, was observed in this sweep as follows:

No.	Chronometer.	Wire.	Index.
	h m s		° ′ ″
73	3 38 14·0	1	1 9 0

And the process of reduction stands as follows:

	h	m	s			°	′	″
Chronom.	3	38	14·0	Index	−	1	9	0
A.	−0	1	38·7	a	+39	1	0	
$B^{(1)}$.	+0	0	0·8	N. P. D. 1830·0	=37	52	0	
R. A. 1830·0.	=3	36	36·1					

With regard to the limits of probable error in the determination of places of such objects as have been only once observed, and which therefore admit of no check by the context, it may be right to say a few words. I consider the probable error of a single good observation, free from mistakes in the readings and reductions, and occurring in a tolerably regular sweep, in which the zero stars are in sufficient number, not to exceed a second and a half of time in R. A. and 30″ in P. D. Mistakes, however, will unavoidably occur in the wire observed, in the minute of time (owing to misadjustment of the chronometer hand), and in the numerical process of reduction. All these are sure to be detected, and are easily corrected, when two or more observations of an object exist; but when one only has been obtained, it remains liable to them all. I can only hope that such cases are not numerous. There is, however, one mode in which a mistake in the R. A. may arise, not so easily detected, and which though of rare occurrence, has certainly been committed occasionally, and has no doubt been the cause of some, if not all, the very bad discordances between right ascensions determined in different sweeps. This is when the position wire of the micrometer, having been left in a direction nearly parallel to the meridian, has been mistaken for one of the fixed wires of the eye-piece, and the transit of the object over this, registered, in lieu of its passage across the true first or second wire. The error thus produced may be of any amount less than the interval of the wires, and though habitually guarded against by setting the position wire obliquely after reading off, has evidently crept in, in some few cases, by the neglect of this precaution.

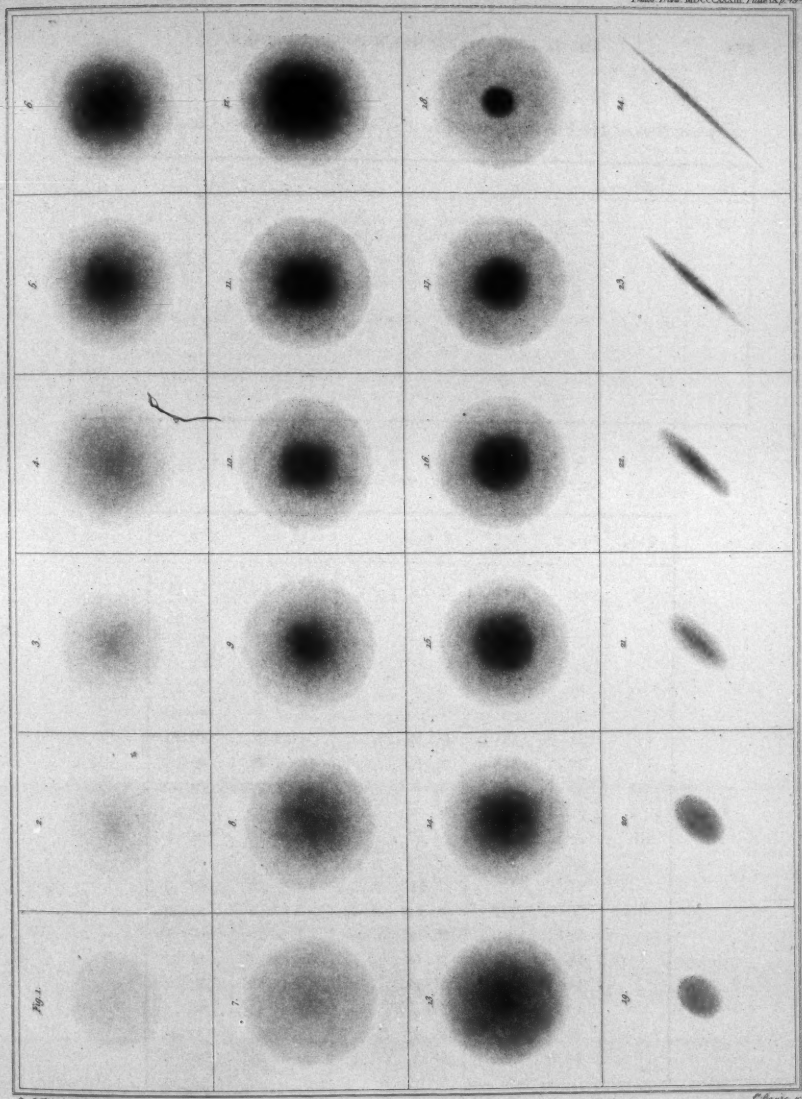
With respect to the discrepances, and apparent contradictions, which will be found in the descriptions of one and the same nebula in different sweeps, they are to be accounted for by differences in the states of the atmosphere, the mirror, and the eye, and will not appear at all surprising to any one accustomed to observation of this nature. At the same time they will serve to show what caution we ought to use in admitting such discordances between descriptions of different observers furnished with different telescopes, as evidences of real changes in any nebula.

Explanation of the PLATES, *with a List of the Nebulæ figured in this Paper.*

Plate.	Figure.	
IX.	1.... 6	Figures illustrative of degrees of brightness. Fig. 1. eF; Fig. 2. vF; Fig. 3. F; Fig. 4. pB; Fig. 5. B; Fig. 6. vB.
	7....12	Figures illustrative of degrees of central brightness. Fig. 7. vlbM; Fig. 8. lbM; Fig. 9. bM; Fig. 10. pmbM; Fig. 11. mbM; Fig. 12. vmbM.
	13....18	Figures illustrative of gradations of brightness from without inwards. Fig. 13. vgbM; Fig. 14. gbM; Fig. 15. bM; Fig. 16. pmbM; Fig. 17. mbM; Fig. 18. vmbM.
	19....24	Figures illustrative of degrees of elongation of form. Fig. 19. vlE; Fig. 20. lE; Fig. 21. E; Fig. 22. pmE; Fig. 23. mE; Fig. 24. vmE.

List of figured Nebulæ.

Plate.	Figure.	Number in Observations.	Synonyms.	R. A.	N. P. D.
				h m s	° ′
X.	25	1622	M. 51	13 22 39	41 56
	26	2060	M. 27	19 52 12	67 44
	27	1486	M. 64	12 48 23	67 23
	28	218	V. 19	2 11 58	48 25
	29	2023	M. 57	18 47 13	57 11
	30	2002	Nova	18 7 1	109 56
	31	311	IV. 69	3 58 36	59 40
	32	838	M. 97	11 4 49	34 4
XI.	33	2088	V. 15	20 38 39	59 54
	34	2092	V. 14	20 49 20	58 57
XII.	35	2008	M. 17	18 10 45	106 15
	36	368	M. 78	5 38 2	90 1
	37	1357	V. 24	12 27 53	63 5
XIII.	38	112	II. 252.....	1 15 0	77 59
	39	1649	II. 297.....	13 28 53	107 1
	40	731	IV. 60	10 28 7	35 37
	41	1456	M. 94	12 42 52	47 57
	42	1989	Nova	17 44 43	66 53
	43	2051	IV. 73	19 40 19	39 54
	44	2098	IV. 1	20 54 53	102 2



Sir J.F.W. Herschel del.

C. Heath sc.

Fig. 25. N. 1672.

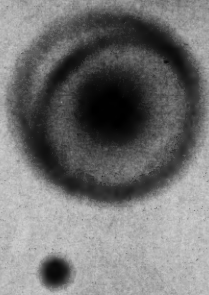


Fig. 26. 2060.

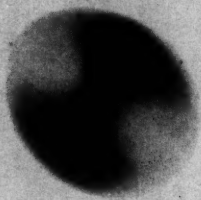


Fig. 27. 1436.

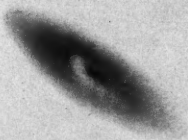


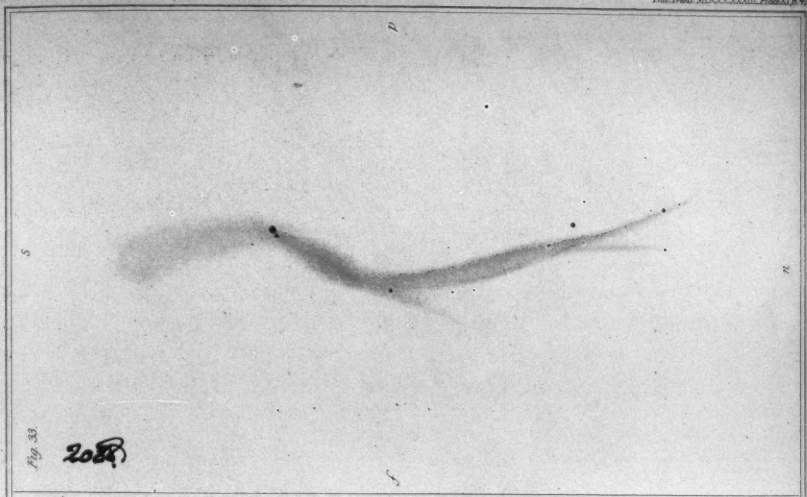
Fig. 28. 212.

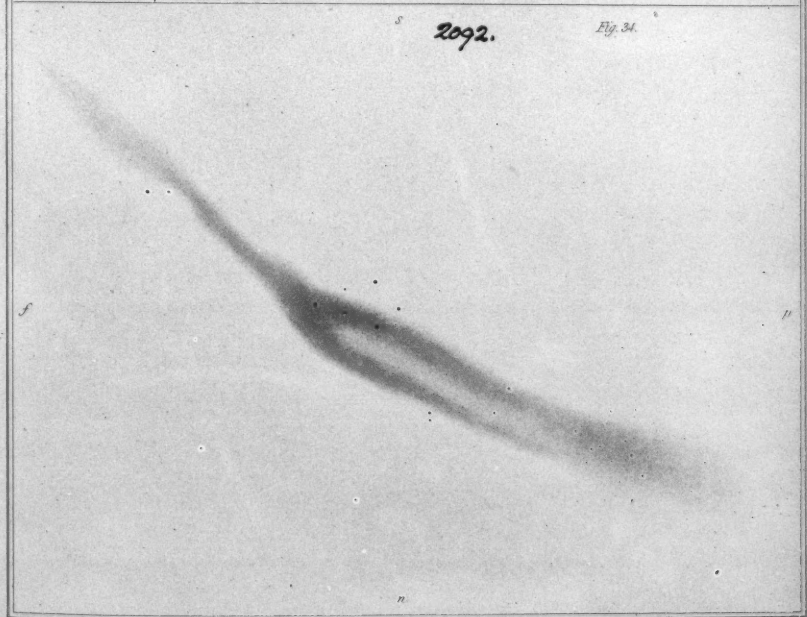
Fig. 29. 2023.

Fig. 30. 2002. ~~2020~~

Fig. 31. 311.

Fig. 32. 838.





Mr. J. F. W. Herschel. del.

F. Chevalier. sc.

Fig. 35. 2008.

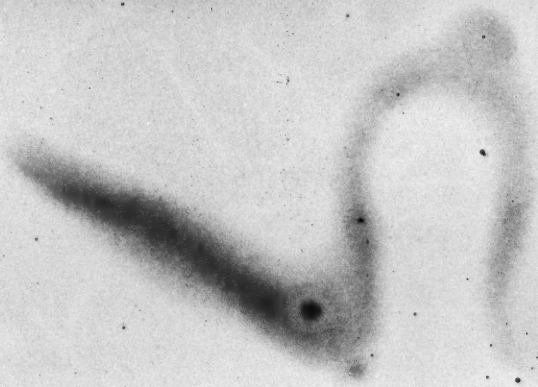
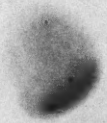


Fig. 36. 8 367



1367 Fig. 37.

Sir J.F.W.Herschel del. F.Chevalier sc.

Fig. 38. Nº 112.

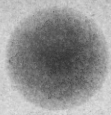


Fig. 39. 1649.

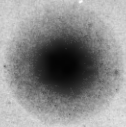


Fig. 40. 731.

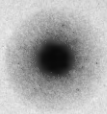


Fig. 41. 1456.

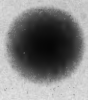


Fig. 42. 1939.

Fig. 43. 2051.

Fig. 44. 2092.

Fig. 45. 2241.

Fig. 46. 2047.

Fig. 47. 2075.

Fig. 48. 2073.

Fig. 49. 385.

Sarah F. W. Hershel del.

C. Hunter sc.

Fig. 50. 1376.

Fig. 51. 859.

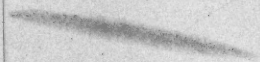


Fig. 52. N. 61.

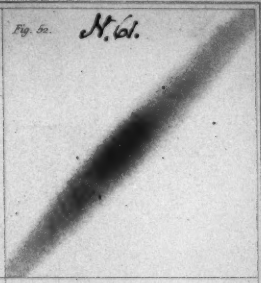


Fig. 53. 3514.

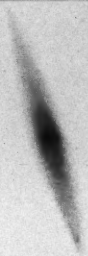
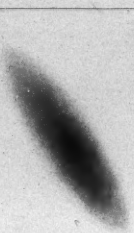


Fig. 54. 876.



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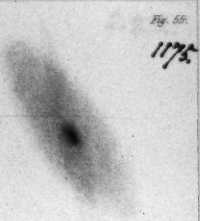

Fig. 56. 242

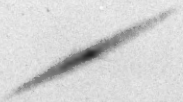

Fig. 57. 1225.

Fig. 59. 1143.

Fig. 58. 151.

Fig. 60. 2226.

Fig. 61. 526.

Fig. 64. 398

Fig. 65. 537.

Fig. 62. 1899

Fig. 63. 2205.

Fig. 66. 962.

Fig. 67. 1629

Sam. F. W. Mundell del.

C. Basire sc.

Fig. 68. 1352.

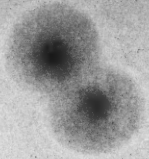

Fig. 69. 1202

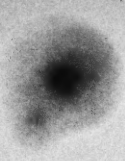

Fig. 70. 604

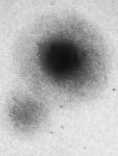

Fig. 71. 1146

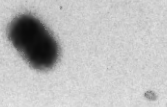

Fig. 72. 444

Fig. 73. 2197

Fig. 74. 1468

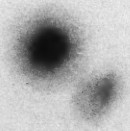

Fig. 75. 1414

Fig. 76. 1397

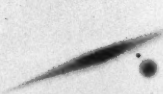

Fig. 77. 1905

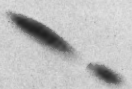

Fig. 78. 1358

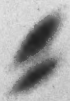

Fig. 79. 936

Fig. 80. 1991

Fig. 81. 357

Fig. 82. 2093

Fig. 83. 1382

Fig. 84. 1466

Fig. 85. 2245

Fig. 86. 1967

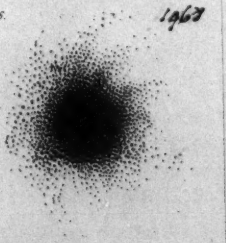

Fig. 87. 1916

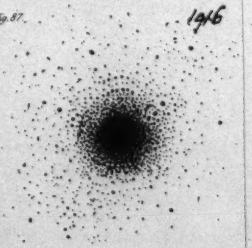

Fig. 88. 2128

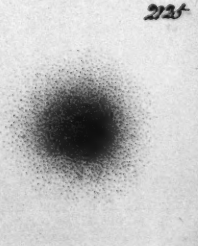

Fig. 89. 1929

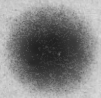

Fig. 90. 2128

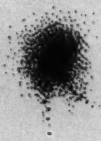

Fig. 91. 425

Lee. J.F.W. Herschel. del.

C. Rosser sc.

List of figured Nebulæ.—Continued.

Plate.	Figure.	Number in Observations.	Synonyms.	R. A.	N. P. D.
				h m s	° ′
XIII.	45	2241	IV. 18	23 17 44	48 24
	46	2047	IV. 51	19 34 21	104 33
	47	2075	IV. 16	20 14 48	70 26
	48	2072	IV. 13	20 9 33	59 57
	49	355	I. 261	5 20 11	55 54
XIV.	50	1376	I. 43.....	12 31 11	100 40
	51	859	V. 8.....	11 11 22	75 28
	52	61	V. 1.....	0 39 12	116 13
	53	854	M. 65	11 10 2	75 59
	54	875	Nova	11 14 12	76 5
	55	1175	V. 43	12 10 33	41 46
	56	242	I. 156	2 29 46	51 41
	57	1225	I. 210	12 15 6	42 4
	58	151	IV. 42.....	1 40 4	84 56
	59	1148	I. 109	12 7 15	75 54
	60	2236	II. 600.....	23 13 58	50 4
	61	536	II. 280.....	8 45 50	92 25
	62	1499	IV. 30.....	12 50 57	54 13
	63	2205	I. 55.....	22 56 26	78 36
	64	399	IV. 2	6 29 53	81 7
	65	537	IV. 66.....	8 46 33	35 35
	66	1362	III. 602	12 28 28	74 48
	67	1509	I. 143	12 52 2	86 35
XV.	68	1252	V. 29	12 17 22	55 31
	69	1202	{M. 61 / I. 139}	12 13 13	84 35
	70	604	I. 56 & 57	9 22 32	67 45
	71	1146	I. 95.....	12 7 5	52 44
	72	444	II. 316 & 317 ..	7 14 50	60 11
	73	2197	II. 450. 451 ..	22 51 12	103 43
	74	1408	M. 60. III. 44..	12 35 4	77 31
	75	1414	I. 176. 177	12 35 39	56 54
	76	1397	V. 42. II. 659..	12 33 54	56 30
	77	1905	II. 751. 752 ..	15 0 0	69 48

List of figured Nebulæ.—Continued.

Plate.	Figure.	Number in Observations.	Synonyms.	R. A.	N. P. D.
				h m s	° ′
XV.	78	1358	Nova	12 27 55	77 49
	79	936	II. 103.....	11 31 24	73 43
XVI.	80	1991	IV. 41.....	17 52 0	113 1
	81	357	M. 1.....	5 24 16	68 7
	82	2093	Nova	20 50 4	60 26
	83	1352	I. 92.....	12 27 31	61 6
	84	1466	II. 75 & 74	12 44 21	77 50
	85	2245	II. 226.....	23 19 58	68 31
	86	1968	M. 13	16 35 37	53 13
	87	1916	M. 5.....	15 9 56	87 16
	88	2125	M. 2.....	21 24 40	91 34
	89	1929	Nova	15 29 9	83 27
	90	2128	M. 30	21 30 42	113 55
	91	415	VI. 2	6 45 18	71 49

Notes on the foregoing List.

Fig. 25. M. 51.—This very singular object is thus described by Messier: —"Nébuleuse sans étoiles." "On ne peut la voir que difficilement avec une lunette ordinaire de 3½ pieds." "Elle est double, ayant chacune un centre brillant eloigné l'un de l'autre de 4′ 35″. Les deux atmosphères se touchent." By this description it is evident that the peculiar phenomena of the nebulous ring which encircles the central nucleus had escaped his observation, as might have been expected from the inferior light of his telescopes. My Father describes it in his observations of Messier's nebulæ (which are not included in his catalogues,) as a bright round nebula, surrounded by a halo or glory at a distance from it, and accompanied with a companion; but I do not find that the partial subdivision of the ring into two branches throughout its south following limb was noticed by him. This is, however, one of its most remarkable and interesting features. Supposing it to consist of stars, the appearance it would present to a spectator placed on a planet attendant on one of them excentrically situated towards the north preceding quarter of the central mass,

would be exactly similar to that of our Milky Way, traversing in a manner precisely analogous the firmament of large stars, into which the central cluster would be seen projected, and (owing to its greater distance) appearing, like it, to consist of stars much smaller than those in other parts of the heavens. Can it, then, be that we have here a brother-system bearing a real physical resemblance and strong analogy of structure to our own? Were it not for the subdivision of the ring, the most obvious analogy would be that of the system of Saturn, and the ideas of LAPLACE respecting the formation of that system would be powerfully recalled by this object. But it is evident that all idea of symmetry caused by rotation on an axis must be relinquished, when we consider that the elliptic form of the inner subdivided portion indicates with extreme probability an elevation of that portion above the plane of the rest, so that the real form must be that of a ring split through half its circumference, and having the split portions set asunder at an angle of about 45° each to the plane of the other.

Fig. 26. MESS. 27.—Described by MESSIER thus: "Nébuleuse sans étoile." "On la voit bien avec une lunette ordinaire de 3½ pieds: elle parait sous une forme ovale et ne contient aucune étoile." In my Father's observations the true form (like that of a double-headed shot or dumb-bell,) was of course distinctly perceived, and the small stars it contains are noticed, and taken as an indication of its resolvability. I incline, however, to the opinion of their being accidental stars (of which multitudes exist in the surrounding region). But here, as in the former object, the feature which gives a peculiar interest to the whole nebula, and alters entirely the light in which its physical constitution must be considered, has been hitherto overlooked,—I mean the faint nebulosity which fills in the lateral concavities of the body, and converts them in fact into protuberances, so as to render the general outline of the whole nebula, a regular ellipse, having for its *shorter* axis the common axis of the two bright masses of which the body consists, that is to say, the *longer* axis of the oval form, under which it was imperfectly seen by MESSIER. To this axis the complete figure is symmetrical, and if we are disposed to regard it as a mass in rotation, it is about this axis that we must suppose it to revolve. In that case its real form must be that of an oblate spheroid; and as it does not follow that the brightest portions must of necessity be the densest, this supposition would

not be incompatible with dynamical laws, at least, supposing its parts to be capable of exerting pressure on one another. But if it consist of discrete stars, this cannot be admitted, and we must have recourse then to other suppositions to account for the maintenance of its form.

Fig. 27. Mess. 64.—The dark semi-elliptic vacancy (indicated by an unshaded or bright portion in the figure,) which partially surrounds the condensed and bright nucleus of this nebula, is of course unnoticed by Messier. It was however seen by my Father, and shown by him to the late Sir Charles Blagden, who likened it to the appearance of *a black eye*, an odd, but not inapt comparison. The nucleus is somewhat elongated, and I have a strong suspicion that it may be a close double star, or extremely condensed double nebula.

Fig. 28. V. 19.—An extraordinary object. Perhaps the representation in the figure is too nicely symmetrical, as it certainly is too sharply defined and distinct. It is of the last degree of faintness, and may very well be unperceived, though full in the field of view. There can hardly be a doubt of its being a thin flat ring, of enormous dimensions, seen very obliquely.

Fig. 29. Mess. 57.—The annular nebula in Lyra. It is ill represented. The edges exhibit a curdled and confused appearance, like stars out of focus. The interior is far from absolutely dark. It is filled with a feeble but very evident nebulous light, which I do not remember to have seen noticed by former observers. Comparing figures 25, 27, 28, 29 and 48, it will appear that the annular form, or an approach to it, is one of those which nebulæ affect, and taken in connexion with the ring of Saturn and the Milky Way, may lead us to conceive that some kind of analogy, however obscure, may subsist in all those cases.

Fig. 33.—The engraving represents this very strange nebula much too intense. It is an extremely faint object. The large double star is *k* Cygni.

Fig. 35. Mess. 17.—The figure of this nebula is nearly that of a Greek capital omega Ω, somewhat distorted and very unequally bright. It is remarkable that this is the form usually attributed to the great nebula in Orion, though in that nebula I confess I can discern no resemblance whatever to the Greek letter. Messier perceived only the bright preceding branch of the nebula now in question, without any of the attached convolutions which were

first noticed by my Father. The chief peculiarities which I have observed in it are, 1st, the resolvable knot in the following portion of the bright branch, which is in a considerable degree insulated from the surrounding nebula; strongly suggesting the idea of an absorption of the nebulous matter; and 2ndly, the much feebler and smaller knot at the north preceding end of the same branch, where the nebula makes a sudden bend at an acute angle. With a view to a more exact representation of this curious nebula, I have at different times taken micrometrical measures of the relative places of the stars in and near it, by which, when laid down as in a chart, its limits may be traced and identified, as I hope soon to have better opportunity to do than its low situation in this latitude will permit.

Fig. 37. V. 24, and Fig. 50. I. 43.—The strong suspicion of a parallel appendage to the latter of these, is almost converted into certainty by its undoubted existence in V. 24, in which it was seen by two other observers as well as by myself. But what are we to make of such an appendage? Must we consider it as an extreme exaggeration of the case of M. 64 (fig. 27), in which the vacancy is extended up to almost the very extremities of the elliptic outline,—in which case the nebula would come to be regarded as a flat annulus seen at a great obliquity, and having very unequal breadths and densities in its two opposite semicircles? Or must we admit the appendage to be a separate and distinct nebula, dependent, by some unknown physical relation, on its brighter neighbour?

Fig. 43.—This remarkable object, as my Father rightly observes, appears to constitute a connecting link between the planetary nebulæ and nebulous stars. It differs from the latter class of objects in respect of the intensity and comparatively sharp termination of the surrounding light; and no less from the former, in that of its stellar centre. With regard to nebulous stars generally, I ought to mention that it has frequently occurred to me to notice a peculiar state of the atmosphere in which all large stars (above the 7th magnitude) have appeared surrounded with photospheres of 2′ or 3′ or more in diameter, precisely resembling that about some of the finer specimens of nebulous stars. The state of the air alluded to, is not that in which fog, or any degree of haziness, or thin strata of cloud are perceptible to the sight. These produce no such appearance. Stars are seen through fog, cloud, or ordinary haze, pre-

cisely as if there were no such intervening medium; only less bright. The photospheres in question are often seen when the sky seems quite pure and clear. They do not arise from dew on the glasses, as is proved by wiping them; nor in the eye itself, for they do not vanish when the star is made to *blink* behind one of the thick wires of the eye-piece; nor in scabrous polish of the mirror, for they are not permanent. They come on suddenly; seldom last very long, and disappear as unexpectedly as they come. When first this phenomenon presented itself, a considerable star which appeared so surrounded was at once set down as a superb nebulous star, and it was not until another and another entered the field similarly affected, that any doubt arose. As regards the true cause of this phenomenon, that it is atmospheric I have no doubt, and perhaps it must be looked for in some highly rarified material, disseminated in cloud-like, though invisible, masses, in the very highest regions of our atmosphere,—the same possibly which, when ignited by the passage of electric currents, gives rise to many if not all the phenomena of the aurora borealis. Be that as it may, the fact that an appearance, exactly resembling that of a nebulous star, may originate in a non-luminous medium, interposed between the eye and the star, serves to render it not improbable that such matter may exist, disseminated through the ether itself in determinate localities, and may render some stars which shine through it nebulous, which have no real nebulous atmospheres about them. The frequency of nebulous stars in the constellation of Orion seems to afford some support to this idea, though I am far from contending that there are no stars really nebulous. Of such the object immediately under consideration, indeed, must be regarded as an undoubted instance.

Figs. 44 .... 47.—Planetary nebulæ. The point to which I should here draw attention is the frequent and close proximity to these objects, of minute stars, which suggest the idea of accompanying satellites. Such they may possibly be. The enormous magnitude of these bodies, and consequent probable mass (if they be not hollow shells), may give them a gravitating energy, which, however rare we may conceive them to be, may yet be capable of retaining in orbits, three or four times their own diameter, and in periods of great length, small bodies of a stellar character. In this point of view a continued series of the angles of position of their companions, micrometrically measured with

due care, would be interesting; and I regret not having sufficiently attended to this in my observations, the few measures given, being hurried, imperfect and discordant.

Plate XIV. Figs. 50..., 67.—*Long nebulæ.* The general form of elongated nebulæ is elliptic, and their condensation towards the centre is almost invariably such as would arise from the superposition of luminous elliptic strata, increasing in density towards the centre. In many cases (as in fig. 53,) this increase of density is obviously attended with a diminution of ellipticity, or a nearer approach to the globular form in the central than in the exterior strata. It is probably owing to this, that extended nebulæ seen in dull or hazy states of the sky are often described as *round*, the fainter and more elliptic envelopes being obliterated, and only the more globular nuclei perceived. The great extension of some nebulæ into long lenticular rays, and the existence of every intermediate degree of ellipticity up to the exact circular form, with the various degrees of rapidity of central condensation, from a barely perceptible increase of density to a seemingly solid nucleus, are all accounted for by supposing the general constitution of these nebulæ to be that of oblate spheroidal masses of every degree of flatness from the sphere to the disc, and of every variety in respect of the law of their density and ellipticity towards the centre. It would be incorrect, however, to draw from this any inference as to the identity of the forces which maintain them in this form with those which determine the oblate spheroidal form of a revolving fluid mass under the dominion of the law of gravitation, and subject to compression by the superincumbent matter. If a nebula be nothing more than a cluster of discrete stars, (as we have every reason to believe, at least in the generality of cases,) no pressure can be propagated through it; and its equilibrium, or, to speak more correctly, the permanence of its form, must be maintained in a way totally different. In a system so constituted, no general rotation of the whole, as a mass, can be supposed. It must rather be conceived as a *quiescent form*, comprising within its limits an indefinite multitude of individual constituents, which, for aught we can tell, may be moving one among the other, each animated by its own inherent projectile force, and deflected into an orbit more or less complicated, by the influence of that law of internal gravitation which may result from the compounded attractions of all its parts. I have

shown elsewhere* how a quiescent spherical form may subsist as the bounding outline of an immense number of equal stars uniformly distributed through its extent, each of which individually atracts all the others with a force inversely as the square of the distance, and whose united attractions compose an internal force on each, directly proportional to the distance from the centre of the sphere. In such a state of things, each star might describe an ellipse in any plane, and in any direction in that plane about the common centre, without the possibility of collision; but the sphere, regarded as a whole, would have no rotation about any axis. If the form be not spherical, and the distribution of the stars not homogeneous, the dynamical relations become too complicated to be distinctly apprehended, yet we may still conceive that something of an analogous result may subsist, and that both the external form and the internal density may be maintained (at least under certain conditions,) for the mass as a quiescent whole, while all its elements are in a state of unceasing transfer and interchange.

Plate XV. Figs. 68....79.—*Double nebulæ.* All the varieties of double stars, as to distance, position and relative brightness, have their counterparts in double nebulæ; besides which, the varieties of form and gradation of light in the latter afford room for combinations peculiar to this class of objects. The series of figures expressed in this Plate exhibits a considerable number of these combinations; and it will, I think, be found impossible, on casting our eye over its contents, and referring mentally to the great number of similar objects scattered through the heavens, to refuse our assent to the idea of a more intimate physical relation between the individuals of a double nebula than that of mere casual juxtaposition. The argument drawn from the comparative rarity of the objects in proportion to the whole extent of the heavens, so cogent in the case of the double stars, is infinitely more so in that of the double nebulæ. Nebulæ, for example, so large and faint, and so little condensed towards the centre as those of V. 29, (fig. 68,) are extremely rare, even single, so that the improbability of two such, casually occurring, so near together as to mix their nebulosities, is extreme. It will therefore become a very interesting subject of future inquiry, whether any traces of orbitual motion (indicated by a progressive change in their angles of position with respect to the meri-

* Cabinet Cyclopædia, Astronomy, last page.

dian,) can be detected in these combinations. The micrometrical measures of many of them which occur in the foregoing observations, though neither so numerous nor so accurate as might be wished, will at least serve as terms of rough comparison, sufficient at least for the detection of rapid rotations.

Plate XVI. Figs. 80, 82, 83, 84, 85 represent nebulæ which offer some remarkable peculiarity of situation with respect to stars. Of these the most singular are IV. 41, (fig. 80,) and that of fig. 82. The latter, however, is very imperfectly expressed in the drawing. Indeed it would be excessively difficult to execute a drawing of such an object with any pretensions to correctness. In this, general resemblance and character only has been aimed at, enough to express the peculiar feature of the object, which is a network or tracery of nebulæ following the lines of a similar network of stars. It is an extremely faint and difficult object, and only once observed; but I do not think it possible I could have been deceived as to the reality of the phenomenon, especially since the brighter parts of the nebula are stated in the observation to have been distinctly seen.

Figs. 81, 86, 87, 88, 89, 90, 91 are clusters of stars, beginning with a barely resolvable one, (M. 1. fig. 81,) and ascending by successive degrees,—figs. 89, 88, 87,—to M. 13, fig. 86, which is one of the most magnificent assemblages of stars the heavens contain. They are instructive, exhibiting, as they do, an analysis of the intimate structure of nebulæ, on which depend many of the peculiarities of their appearance when no stars can be actually discerned in them, such as, for example, that peculiar character to which, when it has occurred, the epithet "hairy" or "filamentous" has been attached in the descriptions, and which is well illustrated by the figure (fig. 86) of MESSIER's 13th, and by the description of the 53rd of the Connaissance des Tems (No. 1558 in the above observations,) as set down in sweep 63; the border, instead of melting away insensibly, having a ragged or fibrous appearance. Again, fig. 90, if removed far enough to lose the stars, would be described, doubtless, as irregularly round or unsymmetrical, if not as having a bifid or forked tail: and fig. 91 (VI. 2,) would, under similar circumstances of removal, appear as a fan-shaped nebula with a bright point like a star at the vertex, such as is represented in figs. 65, 66, 67, 68.

Before terminating this Appendix, it should be explained what is meant by

the references, so frequent in the observations, to a "working list." It has been my invariable practice to prepare before each night's sweep a list, in order of R. A. with approximate polar distances, of the principal objects occurring within the zone intended to be embraced in the sweep, and about 5′ or 10′ above and below it. It is needless to mention that the nebulæ of these lists were mostly those of my Father's sweeps,—not, however, as taken merely from his printed catalogue, in which only references of their places to the nearest large stars are stated, but as reduced and digested (with great patience and care) into a regular catalogue in zones, by my aunt, Miss Caroline Herschel. This valuable MS., which performs the same office with regard to my Father's sweeps, as far as concerns the places of the nebulæ, as the present digested and reduced series of observations does to my own, has therefore been, in point of fact, the groundwork of my whole proceedings, and I should be not only ungrateful, but in a high degree unjust, were I to omit in this place acknowledging the advantage I have derived from its use.

At the commencement of my sweeps, I contented myself, however, with a bare notice of the chief expected nebulæ, but finding that owing to the interest excited by these objects, the zero stars were too much neglected, and smaller nebulæ missed, these came to be inserted at convenient intervals. Subsequently, too, the double stars of Struve's catalogue began to be entered on the lists; and at length, experience having shown me that no trouble bestowed on the construction of an ample and exact "working list" could be considered ill bestowed, I threw aside all the earlier lists of this sort, and dividing the heavens into zones of polar distance, of 3° in breadth from 0° to 120°, proceeded to construct a series of lists or approximate catalogues in order of R. A. for 1830, in which should be comprised the following objects:

1st. All my Father's nebulæ and clusters.

2nd. Messier's ditto.

3rd. All other nebulæ and clusters of which any hints could anywhere be found, including new ones from my own sweeps, inserted from time to time.

4th. All the double stars of Struve's greater catalogue.

5th. All other remarkable double stars of which any record could be found, either in my own sweeps or elsewhere.

6th. A series of zero stars, chosen so as to interfere as little as possible with

the other objects, and selected from the catalogue of the Astronomical Society; or where none fit for the purpose could be found there, from Piazzi's; or failing that, from other authorities.

The construction of the "working lists" on this extended scale, has formed a very large part of the regular work of my sweeps; but so far from regretting the trouble they have cost, or regarding it as waste labour, I can only lament having deferred their full execution till impressed by the experience of much more, and far more valuable observing time lost, with a sense of their importance.

One consequence of the construction of the working lists has been the gradual accumulation of a pretty extensive catalogue of missing nebulæ;—perhaps it would be more correct to say, nebulæ not found when looked for. The fainter nebulæ are so easily overlooked, even when in the field of view, and are altogether such very delicate objects, that it is the most difficult thing in the world to prove the negative proposition as to their existence. Many such cases, too, must have originated in mistaken entries on the list, some doubtless in mistakes in the observations from which those lists were constructed, and some from actually looking in the wrong places by mistaken settings of the telescope. Aware of all these possibilities, I have thought it best to suppress this list for the present, having had no time to go into an examination of the subject. Indeed I doubt whether it would be worth while to do so. There seems very little probability that a real nebula should have disappeared from the heavens; and though some few telescopic comets may have been noticed in my Father's sweeps, and set down as nebulæ, the chances are almost infinite against any such observation, if ascertained, proving of use as a datum for improving the elements of any recorded comet.

XX. *Experimental Researches in Electricity.—Fourth Series.* By Michael Faraday, *D.C.L. F.R.S. M.R.I. &c. &c. &c., Fullerian Prof. Chem. Royal Institution, Corr. Mem. Royal Acad. of Sciences, Paris, Petersburgh, Florence, Copenhagen, Berlin, &c. &c.*

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§ 9. *On a new Law of Electric Conduction.* § 10. *On Conducting Power generally.*

§ 9. *On a new Law of Electric Conduction.*

380. It was during the progress of investigations relating to electro-chemical decomposition, which I still have to submit to the Royal Society, that I encountered effects due to a very general law of electric conduction not hitherto recognised; and though they prevented me from obtaining the condition I sought for, they afforded abundant compensation for the momentary disappointment, by the new and important interest which they gave to an extensive part of electrical science.

381. I was working with ice, and the solids resulting from the freezing of solutions, arranged either as barriers across a substance to be decomposed, or as the actual poles of a voltaic battery, that I might trace and catch certain elements in their transit, when I was suddenly stopped in my progress by finding that ice was a non-conductor of electricity; and that as soon as a thin film of it was interposed, in the circuit of a very powerful voltaic battery, the transmission of electricity was prevented, and all decomposition ceased.

382. At first the experiments were made with ordinary ice, during the cold freezing weather of the latter end of January (1833); but the results were fallacious, from the imperfection of the arrangements, and the following more unexceptionable form of experiment was adopted.

383. Tin vessels were formed, open at one extremity, five inches deep, one

inch and a quarter wide in one direction, and of different widths, from three eighths to five eighths of an inch, in the other. Into these were fixed by corks, plates of platina, so that the latter should not touch the tin cases; and copper wires having previously been soldered to the plates, these were easily connected, when required, with a voltaic pile. Then distilled water, previously boiled for three hours, was poured into the vessels, and frozen by a mixture of salt and snow, so that pure transparent solid ice intervened between the platina and tin; and finally these metals were connected with the opposite extremities of the voltaic apparatus, a galvanometer being at the same time included in the circuit.

384. In the first experiment, the platina pole was three inches and a half long, and seven eighths of an inch wide; it was wholly immersed in the water or ice, and as the vessel was four eighths of an inch in width, the average thickness of the intervening ice was only a quarter of an inch, and the surface of contact with it at both poles equal to nearly fourteen square inches. After the water was frozen, the vessel was still retained in the frigorific mixture, whilst contact between the tin and platina respectively was made with the extremities of a well charged voltaic battery, consisting of twenty pairs of four-inch plates, each with double coppers. Not the slightest deflection of the galvanometer needle occurred.

385. On taking the frozen arrangement out of the cold mixture, and applying warmth to the bottom of the tin case, so as to melt part of the ice, the connexion with the battery being retained, the needle did not at first move; and it was only when the thawing process had extended so far as to liquefy part of the ice touching the platina pole, that conduction took place; but then it occurred effectually, and the galvanometer needle was permanently deflected nearly 70°.

386. In another experiment, a platina spatula, five inches in length and seven eighths of an inch in width, had four inches fixed in the ice, and the latter was only three sixteenths of an inch thick between one metal and the other; yet this arrangement insulated as perfectly as the former.

387. Upon pouring a little water in at the top of this vessel on the ice, still the arrangement did not conduct; yet fluid water was evidently there. This effect was found to be dependent on the cold metals having frozen the

water where they touched it, and thus insulating the fluid part; and it well illustrates the nonconducting power of ice, by showing how thin a film could prevent the transmission of the battery current. Upon thawing parts of this thin film, where it touched *both* metals, conduction occurred.

388. Upon warming the tin and removing the piece of ice, it was found that from a cork having slipped, one of the edges of the platina had been all but in contact with the inner surface of the tin vessel; yet, notwithstanding the extreme thinness of the interfering ice in this place, no sensible portion of electricity had passed.

389. These experiments were repeated many times with the same results. At last a battery of fifteen troughs, or one hundred and fifty pairs of four-inch plates, powerfully charged, was used; yet even here no sensible quantity of electricity passed the thin barrier of ice.

390. It seemed at first as if occasional departures from these effects occurred; but they could always be traced to some interfering circumstances. The water should in every instance be well frozen; for though it is not necessary that the ice should reach from pole to pole, since a barrier of it about one pole would be quite sufficient to prevent conduction, yet, if part remain fluid, the mere necessary exposure of the apparatus to the air, or the approximation of the hands, is sufficient to produce, at the upper surface of the water and ice, a film of fluid extending from the platina to the tin; and then conduction occurs. Again, if corks are used to block the platina in its place, and these corks being immersed, are damp or wet within, it is needful that the cold be sufficiently well applied to freeze the water within them, or else when the surfaces of their contact with the tin become slightly warm by handling, that part will conduct, and the interior being ready to conduct also, the current will pass. The water should be pure, not only that unembarrassed results may be obtained, but also that, as the freezing proceeds, a minute portion of concentrated saline solution may not be formed, which remaining fluid, and being interposed in the ice, or passing into cracks from contraction, may exhibit conducting powers independent of the ice itself.

391. On one occasion I was surprised to find that after thawing much of the ice the conducting power had not been restored; but I found that a cork

which held the wire just where it joined the platina, dipped so far into the ice, that with the ice itself it protected the platina from contact with the melted part long after that contact was expected.

392. This insulation exhibited by ice is not effective with electricity of exalted intensity. On touching a diverged gold-leaf electrometer with a wire connected with the platina, whilst the tin case was touched by the hand or another wire, the electrometer was instantly discharged (419.).

393. But though electricity of an intensity so low that it cannot diverge the electrometer, can still pass (though in very limited quantities (419.),) through ice; the comparative relation of water and ice to the electricity of the voltaic apparatus is not less extraordinary on that account, or less important in its consequences.

394. As it did not seem likely that this law of the assumption of conducting power during liquefaction, and loss of it during congelation, should be peculiar to water, I immediately proceeded to ascertain its influence in other cases, and found it to be very general. For this purpose bodies were chosen which, being solid at common temperatures, were fusible; and of such composition as, for other reasons connected with electro-chemical action, led to the conclusion that they would be able to replace water. A voltaic battery of two troughs, or twenty pairs of four-inch plates (384.), was used as the source of electricity, and a galvanometer introduced into the circuit to indicate the presence or absence of a current.

395. On fusing a little chloride of lead by a spirit-lamp on a fragment of a Florence flask, and introducing two platina wires connected with the poles of the battery, there was instantly powerful action, the galvanometer was most violently affected, and the chloride rapidly decomposed. On removing the lamp, the instant the chloride solidified all current and consequent effects ceased, though the platina wires remained inclosed in the chloride not more than the one-sixteenth of an inch from each other. On renewing the heat, as soon as the fusion had proceeded far enough to allow liquid matter to connect the poles, the electrical current instantly passed.

396. On fusing the chloride, with one wire introduced, and then touching the liquid with the other, the latter (being cold,) caused a little knob to con-

crete on its extremity, and no current passed; and it was only when the wire became so hot as to be able to allow contact with the liquid matter, that conduction took place; and then it was very powerful.

397. When chloride of silver and chlorate of potassa were experimented with, in a similar manner, exactly the same results occurred.

398. Whenever the current passed in these cases, there was decomposition of the substances; but the electro-chemical part of this subject I purpose connecting with more general views in a future paper*.

399. Other substances, which could not be melted on glass, were fused by the lamp and blowpipe on platina connected with one pole of the battery, and then a wire, connected with the other, dipped into them. In this way mixed carbonates of potash and soda, chloride of sodium, sulphate of soda, protoxide of lead, &c. &c. &c., exhibited exactly the same phenomena as those already described. Whilst liquid, they conducted and were decomposed; whilst solid, though very hot, they insulated the battery current even when four troughs were used.

400. Occasionally the substances were contained in small bent tubes of green glass, and when fused, the platina poles introduced, one on each side. In such cases the same general results as those already described were procured; but a further advantage was obtained, namely, that whilst the substance was conducting and decomposing, the final arrangement of the elements could be observed. Thus, iodides of potassium and lead gave iodine at the positive pole, and potassium or lead at the negative pole. Chlorides of iodine and silver gave chlorine at the positive, and metals at the negative pole. Nitre and chlorate of potassa gave oxygen, &c., at the positive, and alkali, or even potassium, at the negative pole.

401. A fourth arrangement was used for substances requiring very high temperature for their fusion. A platina wire was connected with one pole of

* In 1801, Sir H. Davy knew that "dry nitre, caustic potash, and soda are conductors of galvanism when rendered fluid by a high degree of heat," (Journals of the Royal Institution, 1802, p. 53,) but was not aware of the general law which I have been engaged in developing. It is remarkable, that eleven years after that, he should say, "There are no fluids known except such as contain water, which are capable of being made the medium of connexion between the metal or metals of the voltaic apparatus." Elements of Chemical Philosophy, p. 169.

the battery; its extremity bent into a small ring, in the manner described by Berzelius, for blowpipe experiments; a little of the salt, glass, or other substance, was melted on this ring by the ordinary blowpipe, or even in some cases by the oxy-hydrogen blowpipe, and when the drop, retained in its place by the ring, was thoroughly hot and fluid, a platina wire from the opposite pole of the battery was made to touch it, and the effects observed.

402. The following are various substances taken from very different classes, chemically considered, which are subject to this law. The list might, no doubt, be enormously extended; but I have not had time to do more than confirm the law by a sufficient number of instances.

First, *water*.

Amongst *oxides*;—potassa, protoxide of lead, glass of antimony, protoxide of antimony, oxide of bismuth.

Chlorides of potassium, sodium, barium, strontium, calcium, magnesium, manganese, zinc, copper (proto-), lead, tin (proto-), antimony, silver.

Iodides of potassum, zinc and lead, protiodide of tin, periodide of mercury; fluoride of potassium; cyanide of potassium; sulpho-cyanide of potassium.

Salts. Chlorate of potassa; nitrates of potassa, soda, baryta, strontia, lead, copper, and silver; sulphates of soda and lead, proto-sulphate of mercury; phosphates of potassa, soda, lead, copper, phosphoric glass or acid phosphate of lime; carbonates of potassa and soda, mingled and separate; borax, borate of lead, per-borate of tin; chromate of potassa, bi-chromate of potassa, chromate of lead; acetate of potassa.

Sulphurets. Sulphuret of antimony, sulphuret of potassium made by reducing sulphate of potassa by hydrogen; ordinary sulphuret of potassa.

Silicated potassa; chameleon mineral.

403. It is highly interesting in the instances of those substances which soften before they liquefy, to observe at what period the conducting power is acquired, and to what degree it is exalted by perfect fluidity. Thus, with the borate of lead, when heated by the lamp upon glass, it becomes as soft as treacle, but it did not conduct, and it was only when urged by the blowpipe and brought to a fair red heat, that it conducted. When rendered quite liquid, it conducted with extreme facility.

404. I do not mean to deny that part of the increased conducting power in

these cases of softening was probably due to the elevation of temperature (432. 445.); but I have no doubt that by far the greater part was due to the influence of the general law already demonstrated, and which in these instances came gradually, instead of suddenly, into operation.

405. The following are bodies which acquired no conducting power upon assuming the liquid state:—

Sulphur, phosphorus; iodide of sulphur, per-iodide of tin; orpiment, realgar; glacial acetic acid, mixed margaric and oleic acids, artificial camphor; caffeine, sugar, adipocire, stearine of cocoa-nut oil, spermaceti, camphor, naphthaline, resin, gum sandarach, shell lac.

406. Perchloride of tin, chloride of arsenic, and the hydrated chloride of arsenic, being liquids, had no sensible conducting power indicated by the galvanometer, nor were they decomposed.

407. Some of the above substances are sufficiently remarkable as exceptions to the general law governing the former cases. These are orpiment, realgar, acetic acid, artificial camphor, per-iodide of tin, and the chlorides of tin and arsenic. I shall have occasion to refer to these cases in the paper on Electrochemical Decomposition.

408. Boracic acid was raised to the highest possible temperature by an oxyhydrogen flame (401.), yet it gained no conducting powers sufficient to affect the galvanometer, and underwent no apparent voltaic decomposition. It seemed to be quite as bad a conductor as air. Green bottle-glass, heated in the same manner, did not gain conducting power sensible to the galvanometer. Flint glass, when highly heated, did conduct a little and decompose; and as the proportion of potash or oxide of lead increased in the glass, the effects were more powerful. Those glasses, consisting of boracic acid on the one hand, and oxide of lead or potassa on the other, show the assumption of conducting power upon fusion and the accompanying decomposition very well.

409. I was very anxious to try the general experiment with sulphuric acid, of about specific gravity 1·783, containing that proportion of water which gives it the power of crystallizing at 40° Fahr.; but I found it impossible to obtain it so that I could be sure the whole would congeal even at 0° Fahr. A ten-thousandth part of water, more or less than necessary, would, upon cooling the whole, cause a portion of uncongealable liquid to separate, and that remaining

in the interstices of the solid mass, and moistening the planes of division, would prevent the correct observation of the phenomena due to entire solidification and subsequent liquefaction.

410. With regard to those substances on which conducting power is conferred by liquidity, the degree of power so given is generally very great. Water is that body in which this acquired power is feeblest. In the various oxides, chlorides, salts, &c. &c., it is given in a much higher degree. I have not had time to measure the conducting power in these cases, but it is apparently some hundred times that of pure water. The increased conducting power known to be given to water by the addition of salts, would seem to be in a great degree dependent upon the high conducting power of these bodies when in the liquid state, that state being given them for the time, not by heat but solution in the water.

411. Whether the conducting power of these liquefied bodies is a consequence of their decomposition or not (413.), or whether the two actions of conduction and decomposition are essentially connected or not, would introduce no difference affecting the probable accuracy of the preceding statement.

412. This general assumption of conducting power by bodies as soon as they pass from the solid to the liquid state, offers a new and extraordinary character, the existence of which, as far as I know, has not before been suspected; and it seems importantly connected with some properties and relations of the particles of matter which I may now briefly point out.

413. In almost all the instances, as yet observed, which are governed by this law, the substances experimented with have been those which were not only compound bodies, but such as contain elements known to arrange themselves at the opposite poles, and also such as could be decomposed by the electrical current. When conduction took place, decomposition occurred; when decomposition ceased, conduction ceased also; and it becomes a fair and an important question, Whether the conduction itself may not, wherever the law holds good, be a consequence not merely of the capability, but of the act of decomposition? And that question may be accompanied by another, namely, Whether solidification does not prevent conduction, merely by chaining the particles to their places, under the influence of aggregation, and preventing their final separation in the manner necessary for decomposition?

414. But, on the other hand, there is one substance (and others may occur), the per-iodide of mercury, which, being experimented with like the others (400.), was found to insulate when solid, and to acquire conducting power when fluid; yet it did not seem to undergo decomposition in the latter case.

415. Again, there are many substances which contain elements such as would be expected to arrange themselves at the opposite poles of the pile, and therefore in that respect fitted for decomposition, which yet do not conduct. Amongst these are the iodide of sulphur, per-iodide of zinc, per-chloride of tin, chloride of arsenic, hydrated chloride of arsenic, acetic acid, orpiment, realgar, artificial camphor, &c.; and from these it might perhaps be assumed that decomposition is dependent upon conducting power, and not the latter upon the former. The true relation, however, of conduction and decomposition in those bodies governed by the general law which it is the object of this paper to establish, can only be satisfactorily made out after a far more extensive series of observations than those I have yet been able to supply.

416. The relation under this law of the conducting power for electricity to that for heat, is very remarkable, and seems to imply a natural dependence of the two. As the solid becomes a fluid, it loses almost entirely the power of conduction for heat, but gains in a high degree that for electricity; but as it reverts back to the solid state, it gains the power of conducting heat, and loses that of conducting electricity. If, therefore, the properties are not incompatible, still they are most strongly contrasted, one being lost as the other is gained. We may hope, perhaps, hereafter to understand the physical reason of this very extraordinary relation of the two conducting powers, both of which appear to be directly connected with the corpuscular condition of the substances concerned.

417. The assumption of conducting power and a decomposable condition by liquefaction, promises new opportunities of and great facilities in voltaic decomposition. Thus, such bodies as the oxides, chlorides, cyanides, sulphocyanides, fluorides, certain vitreous mixtures, &c. &c., may be submitted to the action of the voltaic battery under new circumstances; and indeed I have already been able, with ten pairs of plates, to decompose common salt, chloride of magnesium, borax, &c. &c., and to obtain sodium, magnesium, boron, &c., in their separate states.

§ 10. *On Conducting Power generally.*

418. It is not my intention here to enter into an examination of all the circumstances connected with conducting power, but to record certain facts and observations which have arisen during recent inquiries, as additions to the general stock of knowledge relating to this point of electrical science.

419. I was anxious, in the first place, to obtain some idea of the conducting power of ice and solid salts for electricity of high tension (392.), that a comparison might be made between it and the large accession of the same power gained upon liquefaction. For this purpose the large electrical machine (290.) was brought into excellent action, its conductor connected with a delicate gold-leaf electrometer, and also with the platina inclosed in the ice, whilst the tin case was connected with the discharging train (292.). On working the machine moderately, the gold leaves barely opened; on working it rapidly, they could be opened nearly two inches. In this instance the tin case was five eighths of an inch in width; and as, after the experiment, the platina plate was found very nearly in the middle of the ice, the average thickness of the latter had been five sixteenths of an inch, and the extent of surface of contact with tin and platina fourteen square inches (384.). Yet, under these circumstances, it was but just able to conduct the small quantity of electricity which this machine could evolve (371.), even when of a tension competent to open the leaves two inches; no wonder, therefore, that it could not conduct any sensible portion of the electricity of the troughs (384.), which, though almost infinitely surpassing that of the machine in quantity, had a tension so low as not to be sensible to an electrometer.

420. In another experiment, the tin case was only four eighths of an inch in width, and it was found afterwards that the platina had been not quite one eighth of an inch distant in the ice from one side of the tin vessel. When this was introduced into the course of the electricity from the machine (419.), the gold leaves could be opened, but not more than half an inch; the thinness of the ice favouring the conduction of the electricity, and permitting the same quantity to pass in the same time, though of a lower tension.

421. Fused iodide of potassium was then introduced into the course of the electricity from the machine. There were two pieces, each about a quarter of

an inch in thickness, and exposing a surface on each side equal to about half a square inch; these were placed upon platina plates, one connected with the machine and electrometer (419.), and the other with the discharging train, whilst a fine platina wire connected the two pieces, resting upon them by its two points. On working the electrical machine, it was possible to open the electrometer leaves about two thirds of an inch.

422. As the platina wire touched only by points, the facts show that this salt is a far better conductor than ice; but as the leaves of the electrometer opened, it is also evident with what difficulty conduction, even of the small portion of electricity produced by the machine, is effected by this body in the solid state, when compared to the facility with which enormous quantities at very low tensions are transmitted by it when in the fluid state.

423. In order to confirm these results by others, obtained from the voltaic battery, one of one hundred and fifty plates, four inches square, was well charged: its action was good; the shock from it strong; the discharge would continue from copper to copper through four tenths of an inch of air, and the gold-leaf electrometer before used could be opened nearly a quarter of an inch.

424. The ice vessel used (420.) was half an inch in width. The extent of contact of the ice with the tin and platina being nearly fourteen square inches, it was equivalent to a plate of ice having a surface of seven square inches of perfect contact at each side, and only one fourth of an inch thick. It was retained in a freezing mixture during the experiment.

425. The order of arrangement in the course of the electric current was as follows. The positive pole of the battery was connected by a wire with the platina plate in the ice; the plate was in contact with the ice, the ice with the tin jacket, the jacket with a wire, which communicated with a piece of tin foil, on which rested one end of a bent platina wire (312.), the other or decomposing end being supported on paper moistened with solution of iodide of potassium (316.): the paper was laid flat on a platina spatula connected with the negative end of the battery. All that part of the arrangement between the ice vessel and the decomposing wire point, including both these, was insulated, so that no electricity might pass through the latter which had not traversed the former also.

426. Under these circumstances, it was found that a pale brown spot of iodine

was slowly formed under the decomposing platina point, thus indicating that ice could conduct a little of the electricity evolved by a voltaic battery charged up to the degree of intensity indicated by the electrometer. But it is quite evident that notwithstanding the enormous quantity of electricity which the battery could furnish, it was, under present circumstances, a very inferior instrument to the ordinary machine; for the latter could send as much through the ice as it could carry, being of a far higher intensity, *i. e.* able to open the electrometer leaves half an inch or more (419. 420.).

427. The decomposing wire and solution of iodide of potassium were then removed, and replaced by a very delicate galvanometer (205.); it was so nearly astatic, that it vibrated to and fro in about sixty-three beats of a watch giving one hundred and fifty beats in a minute. The same feebleness of current as before was still indicated; the galvanometer needle was deflected, but it required to break and make contact three or four times (297.), before the effect was very decided.

428. The galvanometer being removed, two platina plates were connected with the extremities of the wires, and the tongue placed between them, so that the whole charge of the battery, so far as the ice would let it pass, was free to go through the tongue. Whilst standing on the stone floor, there was shock, &c. &c., but when insulated, I could feel no sensation. I think a frog would have been scarcely, if at all, affected.

429. The ice was now removed, and experiments made with other solid bodies, for which purpose they were placed under the end of the decomposing wire instead of the solution of iodide of potassium. For instance, a piece of dry iodide of potassium was placed on the spatula connected with the negative pole of the battery, and the point of the decomposing wire placed upon it, whilst the positive end of the battery communicated with the latter. A brown spot of iodine very slowly appeared, indicating the passage of a little electricity, and agreeing in that respect with the results obtained by the use of the electrical machine (421.). When the galvanometer was introduced into the circuit at the same time with the iodide, it was with difficulty that the action of the current on it could be rendered sensible.

430. A piece of fused common salt being introduced into the circuit was sufficient almost entirely to destroy the action on the galvanometer. Fused

chloride of lead produced the same effect. The conducting power of these bodies, when fluid, is very great (395. 402.).

431. All these effects, produced by using the common machine and the voltaic battery, agree therefore with each other, and with the law laid down in this paper, and also with the opinion I have supported, in the Third Series of these Researches, of the identity of electricity derived from different sources.

432. The effect of heat in increasing the conducting power of many substances, especially for electricity of high tension, is well known. I have lately met with an extraordinary case of this kind, for electricity of low tension, or that of the voltaic pile, and which is in direct contrast with the influence of heat upon metallic bodies, as observed and described by Sir HUMPHRY DAVY*.

433. The substance presenting this effect is sulphuret of silver. It was made by fusing a mixture of precipitated silver and sublimed sulphur, removing the film of silver by a file from the exterior of the fused mass, pulverizing the sulphuret, mingling it with more sulphur, and fusing it again in a green glass tube, so that no air should obtain access during the process. The surface of the sulphuret being again removed by a file or knife, it was considered quite free from uncombined silver.

434. When a piece of this sulphuret, half an inch in thickness, was put between surfaces of platina, terminating the poles of a voltaic battery of twenty pairs of four-inch plates, a galvanometer being also included in the circuit, the needle was slightly deflected, indicating a feeble conducting power. On pressing the platina poles and sulphuret together with the fingers, the conducting power increased as the whole became warm. On applying a lamp under the sulphuret between the poles, the conducting power rose rapidly with the heat, and at last the galvanometer needle jumped into a fixed position, and the sulphuret was found conducting in the manner of a metal. On removing the lamp and allowing the heat to fall, the effects were reversed, the needle at first began to vibrate a little, then gradually left its transverse direction, and at last returned to a position very nearly that which it would take when no current was passing through the galvanometer.

435. Occasionally, when the contact of the sulphuret with the platina poles was good, the battery freshly charged, and the commencing temperature not

* Philosophical Transactions, 1821, p. 431.

too low, the mere current of electricity from the battery was sufficient to raise the temperature of the sulphuret; and then, without any application of extraneous heat, it went on increasing conjointly in temperature and conducting power, until the cooling influence of the air limited the effects. In such cases it was generally necessary to cool the whole purposely, to show the returning series of phenomena.

436. Occasionally, also, the effects would sink of themselves, and could not be renewed until a fresh surface of the sulphuret had been applied to the positive pole. This was in consequence of peculiar results of decomposition, to which I shall have occasion to revert in the section on Electro-chemical Decomposition, and was conveniently avoided by inserting the ends of two pieces of platina wire into the opposite extremities of a portion of sulphuret fused in a glass tube, and placing this arrangement between the poles of the battery.

437. The hot sulphuret of silver conducts sufficiently well to give a bright spark with charcoal, &c. &c., in the manner of a metal.

438. The native grey sulphuret of silver, and the ruby silver ore, both presented the same phenomena. The native malleable sulphuret of silver presented precisely the same appearances as the artificial sulphuret.

439. There is no other body with which I am acquainted, that, like sulphuret of silver, can compare with metals in conducting power for electricity of low tension when hot, but which, unlike them, during cooling, loses in power, whilst they, on the contrary, gain. Probably, however, many others may, when sought for, be found.

440. The proto-sulphuret of iron, the native per-sulphuret of iron, arsenical sulphuret of iron, native yellow sulphuret of copper and iron, grey artificial sulphuret of copper, artificial sulphuret of bismuth, and artificial grey sulphuret of tin, all conduct the voltaic battery current when cold, more or less, some giving sparks like the metals, others not being sufficient for that high effect. They did not seem to conduct better when heated, than before; but I had not time to enter accurately into the investigation of this point. Almost all of them became much heated by the transmission of the current, and present some very interesting phenomena in that respect. The sulphuret of antimony does not conduct sensibly either hot or cold, but is amongst those bodies acquiring conducting power when fused (402.). The sulphuret of silver and

perhaps some others decompose whilst in the solid state; but the phenomena of this decomposition will be reserved for its proper place in the next series of these Researches.

441. Notwithstanding the extreme dissimilarity between sulphuret of silver and gases or vapours, I cannot help suspecting the action of heat upon them to be the same, bringing them all into the same class as conductors of electricity, although with those great differences in degree, which are found to exist under common circumstances. When gases are heated, they increase in conducting power, both for common and voltaic electricity (271.); and it is probable that if we could compress and condense them at the same time, we should still further increase their conducting power. CAGNIARD DE LA TOUR has shown that a substance, for instance water, may be so expanded by heat whilst in the liquid state, or condensed whilst in the vaporous state, that the two states shall coincide at one point, and the transition from one to the other be so gradual that no line of demarcation can be pointed out*; that, in fact, the two states shall become one;—which state presents us at different times with differences in degree as to certain properties and relations; and which diffeences are, under ordinary circumstances, so great as to be equivalent to two different states.

442. I cannot but suppose at present that at that point where the liquid and the gaseous state coincide, the conducting properties are the same for both; but that they diminish as the expansion of the matter into a rarer form takes place by the removal of the necessary pressure; still, however, retaining, as might be expected, the capability of having what feeble conducting power remains, increased by the action of heat.

443. I venture to give the following summary of the conditions of conduction in bodies, not however without fearing that I may have omitted some important points.

444. All bodies conduct electricity in the same manner from metals to lac and gases, but in very different degrees.

445. Conducting power is in some bodies powerfully increased by heat, and in others diminished, yet without our perceiving any accompanying essential

* Annales de Chimie, xxi. pp. 127, 178.

electrical difference, either in the bodies or in the changes occasioned by the electricity conducted.

446. A numerous class of bodies insulating electricity of low intensity when solid, conduct it very freely when fluid, and are then decomposed by it.

447. But there are many fluid bodies which do not sensibly conduct electricity of this low intensity; there are some which conduct it and are not decomposed; nor is fluidity essential to decomposition*.

448. There is but one body yet discovered† which, insulating a voltaic current when solid, and conducting it when fluid, is not decomposed in the latter case (414.).

449. There is no strict electrical distinction of conduction which can, as yet, be drawn between bodies supposed to be elementary, and those known to be compounds.

* See the next series of these Experimental Researches.

† It is just possible that this case may, by more delicate experiment, hereafter disappear.

Royal Institution,
April 15, 1833.

XXI. *Experimental Researches on Atomic Weights.* By Edward Turner, *M.D. F.R.S. Lond. & Ed., Sec. G.S., Professor of Chemistry in the University of London.*

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THE present communication may be viewed as the continuation of an Essay on the Composition of the Chloride of Barium, which was honoured with a place in the Philosophical Transactions for the year 1829. In resuming the subject after such a long interval, I feel it right to apologize to the Society for the unfinished state in which that Essay has hitherto been left,—an omission far from voluntary, and entirely due to circumstances not subject to my own controul. In one point of view, however, the delay has been advantageous: it has afforded an opportunity to chemists to verify or correct the results contained in my first Essay, and has enabled me to repeat and extend my researches.

The object which I proposed to myself in commencing the present inquiry, was to re-examine some of those estimates which chemists have occasion to use continually as elements in their calculations, and to confide in as the foundation of their doctrines. With this view I undertook to determine the relative accuracy of the atomic weights which the British and Continental chemists respectively employ; and several circumstances induced me to begin by analysing the chloride of barium. Dr. Thomson, on whose experiments the British chemists relied, had obtained so many of his results by means of the chloride of barium, that any material error in the constitution of that compound would necessarily vitiate a large part of his table of equivalents; and if, on the other hand, the estimate of Dr. Thomson proved to be correct, an important error would be chargeable against Berzelius, whose numbers are very generally adopted on the Continent. The result of the inquiry is now well known: the source of fallacy, pointed out in my first communication, has been admitted by Dr. Thomson in the new edition of his System of Chemistry*, and he has accordingly changed the equivalent of barium from 70 to 68.

* Seventh Edition, vol. i. p. 427.

The inevitable consequence of this change must be apparent to every one who is acquainted with the method of analysis so frequently resorted to by Dr. Thomson. Many of the experiments described in his First Principles of Chemistry are now at irreconcilable variance with each other, and, if relied upon at all, subvert the conclusions which they once appeared to establish. Nor can those parts of his work which are not subject to this criticism be safely applied to the purposes of science. His view, for instance, of the composition of the compounds of oxygen with phosphorus, arsenic, and antimony, has been lately abandoned by himself*; and in the course of the present Essay I shall have occasion to prove, that the atomic weights which he has employed for silver and chlorine are likewise inadmissible. His analysis of sulphate of zinc, which was made, to use Dr. Thomson's own words, "the foundation on which he endeavoured to rear the whole subsequent doctrine of the atomic weight of bodies†," is peculiarly objectionable. Besides being vitiated by his error in the equivalent of barium, the oxide of zinc was determined by a method which involved an error in principle, and was in practice so complex as to be unfit for the extremely important object which it was intended to serve.

Having shown that the atomic weights current among British chemists, though in some instances correct or sufficiently approximative, have, as a whole, been adopted on insufficient and fallacious evidence, I shall now lay before the Society an account of experiments made for ascertaining the equivalents of lead, chlorine, silver, barium, and nitrogen.

Equivalent of Lead.

Berzelius has made repeated and elaborate researches on the atomic weight of lead, and on the composition of its protoxide. His direct analysis of the oxide by reduction with hydrogen gas, simple as it appears, is liable to practical difficulties, the effect of which may be distinctly traced in the varying results of his experiments. Calculating from the two most discordant of the six analyses which Berzelius has published in his last Essay on this subject‡, the equivalent of lead, compared to oxygen as 8, will be 103·42 in one case, and 103·64 in the other. This difference, considering the simplicity of the method,

* System of Chemistry, Seventh Edition.

† Annals of Philosophy, vol. xxvi. p. 363.

‡ Poggendorff's Annalen, vol. xix. p. 314.

and the large quantities of oxide subjected to analysis, is very far greater than could arise in the hands of Berzelius from the mere accidents of manipulation. One source of error, which however he appears wholly or in great measure to have avoided, is the tendency of the oxide of lead to unite with the siliceous matter of the tube, and thus to escape reduction. Another, not improbable, cause of slight error is referrible to the facility with which spurious distillation ensues when gaseous matter passes over the surface of a hot liquid: by this means small quantities of lead may have been carried away by the hydrogen, and the loss in oxygen thereby rendered too large. Hence the probability is, that the real equivalent of lead is nearer to 103·64 than to 103·42.

Seeing no chance of procuring by means of hydrogen more uniform results than Berzelius obtained, I selected an entirely different method, dependent on the quantity of sulphate of lead which given weights of metallic lead and protoxide of lead respectively produce. The method consists of a few simple operations, which, with the requisite precautions, may be conducted with ease and accuracy. A solution of the best commercial acetate of lead was precipitated by carbonate of ammonia in excess, and the carbonate of lead, after being well washed with distilled water, was dissolved in nitric acid. From the nitrate, purified by repeated crystallization, the lead was again thrown down by carbonate of ammonia, and the carbonate reduced by black flux. The metal was washed, fused in a clean crucible, and poured on a clean stone: before being used, the superficial film of oxide was scraped off with a penknife. In the lead thus prepared I could detect no silver, copper, or other impurity: 100 grains of the metal, oxidized, converted into sulphate, and ignited, yielded to hot water a mere trace of sulphate of potash corresponding to what was introduced by the water and acids which were employed.

Conversion of metallic Lead into Sulphate.—The mode which I found most convenient for converting the metal into sulphate, was to introduce it into the requisite quantity of mixed nitric and sulphuric acid, diluted with an equal volume of water. The vessel employed for the purpose was a small bell jar, such as is used for collecting gases over mercury: when placed in an inclined position on the sand-bath, there was no danger of loss by spirting, the materials could be freely stirred, and the sulphate readily removed by help of a clean feather at the close of the process. The excess of the acids was next decanted

into a platinum capsule two inches and a half in diameter, and expelled by evaporation. The sulphate of lead was then transferred to the same capsule, and gently evaporated to dryness, care being taken that some free sulphuric acid should be present. The capsule was then ignited by the flame of a spirit-lamp with a double wick, and its weight carefully taken before and after its contents were removed. The sulphate of lead should not be evaporated in a crucible, since otherwise the annoyance which Berzelius justly complained of, namely, loss by spirting, will be felt severely: by means of a capsule this inconvenience is entirely avoided. When the quantity of sulphate is abundant, it will be found convenient to transfer most of the salt to a crucible as soon as it is sufficiently dry to form a cake.

To prevent floating particles of dust from falling into the capsule during the evaporation, a disk of glass a foot in diameter was supported just above it, and the glass itself covered with a sheet of paper. Allowance was made for impurities contained in the water and acids. Each of these substances had been twice carefully distilled; but nevertheless, when evaporated, a trace of residue might be perceived: its quantity however was very minute. An ounce of nitric acid, four ounces of water, and 100 grains of sulphuric acid, (being twice as much of each as was employed in any single experiment,) were digested for a whole day on the sand-bath, and the residue was evaporated and ignited, every part of the operation being the same as in the conversion of lead into sulphate. The solid matter, consisting of the sulphates of lime and potash, amounted to 0·03 of a grain, half of which was therefore subtracted from the weight of ignited sulphate of lead in each experiment.

Another precaution, which ought not to be neglected in delicate atomic researches, was suggested to me by Dr. Clark of Glasgow. In the conversion of lead into a sulphate, the same substance is weighed in two different states, its density in one form being 11·358, and 6·298 in the other,—a circumstance productive of a small error, which is appreciable when the difference between the two densities is considerable. I have always avoided this error, when it was of sufficient amount to affect the second place of decimals, by using absolute instead of apparent weights, that is, adding to the weight of each substance in air, the weight of the air which they respectively displace.

The quantity of sulphate of lead yielded by a given weight of metallic lead

is shown by the three following experiments, all corrections being allowed for. They were made after determining on the exact mode of manipulating by several previous trials:—

	Lead.	Sulphate.	Lead.	Sulphate.
Exp. 1.—79·968 grains of metallic lead yielded		117·097, being the ratio of	100	to 146·43
Exp. 2.—63·257		92·607		146·398
Exp. 3.—92·92		136·011		146·375
The mean of the three experiments gave			100	to 146·401

Four experiments of the same kind, published by Berzelius, gave the following numbers*:—

	1.	2.	3.	4.	Mean.
Lead	100	100	100	100	100
Sulphate	146·38	146·4	146·44	146·458	146·419

I adopt the ratio of 100 to 146·41 as being the mean of the whole.

Conversion of Oxide of Lead into Sulphate.—Berzelius has correctly shown that pure protoxide of lead cannot be prepared by decomposing the neutral nitrate by heat in a platinum crucible, since the crucible itself is always attacked, and the resulting oxide of lead intermixed with fine particles of platinum. To avoid this impurity, the oxide was prepared, as Berzelius recommends, from the subnitrate. To a cold solution of the neutral nitrate, pure ammonia was added in slight excess, and the white subnitrate collected on a filter, and dried. It was then introduced into a covered platinum crucible, and was heated for a full hour by a charcoal fire in an open grate, taking care to maintain it at a distinct red heat, but insufficient for fusion. The oxide was thus obtained in a pulverulent state, quite free from platinum, and of a pretty lemon-yellow colour. It ought to dissolve completely and easily in cold dilute acetic acid, yielding a colourless solution, which, on standing, does not deposite any brown particles of peroxide.

I may here mention the mode I adopt for weighing pulverulent or porous substances, so as to avoid the possibility of error from the condensation of air or moisture. The substance is well dried at the requisite temperature, and while hot is introduced into a small flask, capable of holding about an ounce of water, and of bearing a considerable temperature without breaking. The flask

* Annals of Philosophy, vol. xv. p. 96.

and its contents are placed in the sand-bath, and while yet hot a tight cork is inserted: the whole, when cold, is weighed, the required quantity for experiment gently poured out, and the flask again restored to the balance. By this means the weight even of a deliquescent substance may be exactly determined. It is necessary before the first weighing to restore the equilibrium of the air within the flask by a momentary removal of the cork.

A given weight of carefully prepared protoxide of lead was dissolved in hot dilute nitric acid, yielding a perfectly clear colourless solution, and the lead was thrown down by an excess of sulphuric acid. After evaporating the clear liquid, and expelling the nitric acid, the precipitate was transferred into the platinum capsule, and the quantity of sulphate determined in the manner already described. I subjoin several of my results, calculated to 100 parts, with all corrections made: the actual quantity of oxide employed in almost every case exceeded 100 grains. The numerals indicate the order of time in which the experiments were made:—

	1.	2.	3.	4.	5.	6.
Oxide	100	100	100	100	100	100
Sulphate	135·84	135·71	135·84	135·75	135·79	135·78

On comparing the second with the first and third experiments, it was manifest that there was some source of fallacy, since the difference was fully twice as great as I expected to arise from mere error in manipulation. I speedily traced one error by finding, in the second experiment, that some nitrate had escaped decomposition, and by ignition had been left as oxide. This was indicated by a yellow stain, and was proved by digesting the ignited sulphate with dilute nitric acid, when lead was readily taken up. This inconvenience was effectually avoided in the later experiments, by carefully expelling the nitric acid before bringing the precipitate into the capsule, and moistening it with a distinct excess of free sulphuric acid during evaporation.

Another fallacy, which affects all the results above quoted, arose from traces of red lead remaining in the oxide and eluding detection by being decomposed in the hot, rather strong dilute nitric acid which was used as the solvent. I was led to suspect this error by the escape of globules of gas while the oxide was dissolving; and accordingly on taking up a portion in cold acetic acid, the peroxide was readily brought into view. It was this circumstance which

induced me to express a belief, in a short report of these experiments to the British Association last June, that the equivalent of lead would be found rather higher than was then stated. Subsequent observation has justified that statement. Some pure protoxide of lead was prepared as before, and was then a second time kept at a red heat for a whole hour: it dissolved completely in cold dilute acetic acid; and 164·766 grains, treated as in the preceding experiments, yielded 223·943 of sulphate, being in the ratio of 100 to 135·92. Every part of this experiment was successfully performed, and I therefore confide in it as representing the true constitution of sulphate of lead. It is accordingly composed of

Protoxide of lead . .	164·766 grs. . .	100 . .	73·575
Sulphuric acid . . .	59·177 grs. . .	35·92 . .	26·425
	223·943	135·92	100·000

Assuming, agreeably to the experiments already described (page 527), that 100 parts of metallic lead yield 146·41 of the sulphate, or that 100 of the sulphate contain 68·301 of metallic lead, it follows that the oxide consists of

Lead	68·301 . . .	103·6
Oxygen	5·274 . . .	8
	73·575	111·6

The equivalent of lead, according to these results, may be safely estimated at 103·6. It cannot be so high as 104, as is supposed by some British chemists; for according to the numbers current in this country, 100 of metallic lead ought to yield 146·16 of sulphate, instead of 146·41 found experimentally; and agreeably to the same estimates, 100 of the protoxide of lead should yield 135·72, instead of 135·92, the experimental quantity.

Equivalent of Chlorine.

The most conclusive experiments I have met with on this subject, are those of Berzelius. He obtained from 100 parts of chlorate of potash 39·15 of oxygen and 60·85 of chloride of potassium; and he also found that 100 of chloride of potassium correspond to 192·4 of chloride of silver. According to my own experiments, which coincide very closely with those of Berzelius,

100 parts of silver yield 132·8 of the chloride. From these data it follows that the equivalent of chlorine is 35·45.

Chloride of Lead.—To compare with this number the equivalent of chlorine deduced by a different process, some pure carbonate of lead was dissolved in muriatic acid diluted with boiling water, and the purity of the chloride ensured by repeated crystallization. The dry crystals were then fused in a tube filled with dry chlorine gas; and while the chloride was yet warm, the chlorine was displaced from the tube by dry carbonic acid gas. The resulting chloride of lead was colourless, and dissolved completely in hot water. The analysis was performed by decomposing the solution of chloride of lead by carbonate of soda, acidulating the clear solution with nitric acid, and precipitating with nitrate of silver. The carbonate of lead, after being washed, was dissolved in acetic acid, and tested for chlorine. The quantity of chlorine was inferred from the quantity of chloride of silver, and that of lead from the quantity of chlorine. After a few repetitions I obtained uniform results, and subjoin the proportions of the two most successful experiments:

	1.		2.	
Lead	19·582	103·6	23·099	103·6
Chlorine	6·708	35·48	7·901	35·43

These results, then, give an equivalent for chlorine closely agreeing with that calculated from the analysis of chlorate of potash as above quoted from Berzelius. They are, at the same time, entirely inconsistent with the atomic weights current in this country. For, supposing 104, 36, and 110 to be the respective equivalents of lead, chlorine, and silver, it follows that 100 parts of the chloride of lead should yield 104·28 parts of chloride of silver, instead of 103·24 as given by experiment,—a difference very far beyond the reasonable limits of error.

Oxide of Mercury.—Wishing to obtain still further evidence respecting the ratio of the atoms of chlorine and oxygen, I determined on performing a careful comparative analysis of the binoxide and bichloride of mercury. I at first employed some red oxide prepared by myself from the nitrate; and though the analyses made with that substance are subject to a slight error, yet as the side on which the error lies is apparent, it will not be unprofitable to record them. A quantity of oxide of mercury was decomposed in a porcelain retort by a red

heat, and the mercury was received in distilled water. It was well boiled successively with muriatic acid, potash, muriatic acid, and distilled water. The pure metal was oxidized by very pure nitric acid, and the nitrate decomposed by heat, the temperature at the last being urged so fully to a decomposing heat, that some metallic mercury sublimed. This was done to decompose every trace of nitric acid, and it succeeded to a very great extent; but when considerable quantities of the oxide, such as 150 grains, were decomposed by heat, the sublimed mercury exhibited a faint yellow ring, indicative of a small quantity of nitric acid. Even digestion with a solution of potash did not prevent this appearance.

The method of analysis was by the direct action of heat. A given weight of the red oxide, previously exposed to a heat of 600° to expel all trace of metallic mercury, was introduced into a tube of German glass, five eighths of an inch wide, and about ten inches in length; and the oxide was decomposed by the flame of a spirit-lamp, the remainder of the tube being kept cool by moistened paper. The gas as it escaped passed through a bent narrow tube, containing pieces of silver, and ultimately passed over a surface of gold-leaf: this tube was weighed at the beginning and close of each experiment, but in general the quantity of mercury conveyed into it was not appreciable. When the decomposition was complete, the tube was filled with dry carbonic acid gas, and the metal was again distilled. The subjoined numbers contain the results of two experiments performed after acquiring experience in the manual part of the method by several previous trials:

	1.		2.	
Mercury	144·805 grs.	200·768	125·98 grs.	199·968
Oxygen	11·54 grs.	16	10·08 grs.	16

The figures at the left hand of each bracket indicate the quantities actually observed. The oxide employed in the two analyses was prepared at different times. Neither portion was wholly free from nitric acid; and hence it is apparent, as the loss was thereby rendered greater than it ought to be, that the real equivalent of mercury must exceed 200·768.

I next proceeded to analyse peroxide of mercury prepared by heat; and for that purpose a number of pure scales was selected from among a large sample of commercial oxide. On exposure to a temperature of 600°, a portion of me-

tallic mercury was expelled, and the colour of the oxide brightened; indeed, every specimen of oxide which has fallen into my hands contained some free mercury, separable by heat, and due, I presume, to the deoxidizing agency of light. A similar remark was made some years ago by Professor DANIELL. The sample analysed contained likewise 0·01 per cent. of fixed matter, which was silica or peroxide of tin coloured by iron, together with a little lime. Allowance was of course made for it. The following is the result of two careful analyses:

	1.		2.	
Mercury	173·561 grs.	200·94	114·294 grs.	200·93
Oxygen	13·82 grs.	16	9·101 grs.	16

From this it would seem that the equivalent of mercury is not 200 as commonly believed by British chemists, but about 201. For the moment, I adopt this number, and will revert to the subject afterwards.

Bichloride of Mercury.—The corrosive sublimate of commerce was purified by repeated crystallization from distilled water, and was then well dried at its subliming temperature. It might in that state be sublimed without giving any trace of humidity. Of this chloride 137·595 grains were dissolved in warm water, and directly decomposed by nitrate of silver; and the chloride of silver was washed with water acidulated with nitric acid, and amounted in the fused state to 144·374 grains, equivalent to 35·659 of chlorine. The bichloride of mercury would hence seem to be composed of

Mercury	101·936	201
Chlorine	35·659	70·31

giving 35·16 as the equivalent of chlorine. This result led me to suspect some imperfection in the method of analysis; and I accordingly found that some of the bichloride of mercury is apt to combine with the chloride of silver, and being expelled when the latter is fused, a loss of chlorine is occasioned. To avoid this error, the bichloride was decomposed by lime, which was prepared from Carrara marble, and was quite free from muriatic acid. The requisite quantity of lime, previously slaked, was mixed with a little warm water, and the solution of a known weight of corrosive sublimate gradually added, shaking the mixture after each addition. After a short digestion and filtration, the

liquid was neutralized by nitric acid, and the chlorine determined by nitrate of silver in the usual manner. Every trace of muriatic acid may thus, without the necessity of boiling the materials together, be transferred to the lime and rendered soluble, while the oxide of mercury, of an orange colour, is left with the excess of lime. In this way I obtained the three following ratios:—

	1.		2.		3.	
Mercury	113·441	201	113·149	201	112·535	201
Chlorine	39·748	70·428	39·723	70·565	39·433	70·43

According to these results we obtain 35·214, 35·28, 35·26 as the equivalent of chlorine.

Calomel.—The proto-chloride, though much more stable than the protoxide of mercury, is very subject to change. I believe it is impossible to sublime calomel without a portion being resolved into mercury and corrosive sublimate; and after washing calomel, so as to remove the adhering bichloride, the heat subsequently required for rendering it quite dry causes a fresh production of corrosive sublimate. I selected for analysis the pulverulent white calomel prepared by Mr. Howard, and dried it by exposure to a continued heat of 300° Fahr.; at which temperature it undergoes no appreciable decomposition, and contains only a trace of moisture. But that trace of humidity affects the ensuing results with a small error, the tendency of which is to make the equivalent of chlorine smaller than it is. The following are the ratios of three careful analyses, which were made by means of lime, as in the analysis of corrosive sublimate.

	1.		2.		3.	
Mercury	100·048	201	95·154	201	76·565	201
Chlorine	17·602	35·361	16·721	35·32	13·473	35·37.

It will now be convenient to compare together the numbers expressive of the equivalent of chlorine as determined from the four sources above enumerated: these are

	From Chlorate of Potash, (Berzelius.)	Choride of Lead.	Bichloride of Mercury.	Protochloride of Mercury.
Equivalent of chlorine	35·45	35·45	35·28	35·35.

The equivalent of chlorine is thus limited by the numbers 35·28 and 35·45, and the mean is 35·33. Though this number has been obtained by four distinct methods, yet there is one element of the calculation common to all,

namely, the composition of chloride of silver. Should any material error exist in this fundamental point, a doubt may still be raised respecting the equivalent of chlorine; but if we can rely on the constitution of the chloride of silver as here employed, then I should feel no hesitation in confining the equivalent of chlorine within the limits which have just been assigned. Now it happens that on this very question a doubt has been raised by my friend Dr. Prout, whose remarks are always pertinent, being founded on careful observation. Chloride of silver, as Dr. Prout informs me, invariably gives out muriatic acid at a certain stage of drying; and he suggests whether the loss may not be sufficient to influence the atomic weight of chlorine. Into this point I have carefully examined. Nitrate of silver was precipitated by muriatic acid in excess, was well washed with warm water, and set to drain in a dark closet. Exposed to light it acquired an acid reaction; and heated in contact with litmus-paper, the colour was reddened, even though not at the same time under the influence of light. A portion was introduced into a clean retort, and heat applied so as to dry it in that situation, day-light being excluded: the water which thus came over was quite neutral, and the chloride was at length left quite white and dry, without a trace of acid being lost. The same experiment was repeated with the same result. I hence consider it as certain that pure chloride of silver may be completely dried at 300° Fahr. without loss of any acid, if light and organic matter be excluded. On heating this dry and white chloride in a test-tube, a portion of acid sufficient to redden litmus was given out, just as the colour of the chloride darkened in the act of fusing. This phenomenon is constant. To try the amount of the loss, a quantity of pure chloride of silver was well dried at 300° Fahr.; and in one experiment forty-one grains, and in another ninety grains, were fused in a platinum crucible. In neither case did the loss amount to an appreciable quantity: I could not satisfy myself that it reached 0·01 of a grain. In these trials, however, the dry chloride was corked up in the weighing flask while still warm; for if allowed to cool in the open air, it absorbs a little air and moisture, and then on being fused a slight loss is perceptible. These experiments have been preferably made with chloride of silver thrown down from the nitrate by muriatic acid: the results are similar with any pure chloride; but when precipitated by sea-salt, it is apt, unless very carefully washed, to retain a little chloride of sodium, and then I

believe the developement of acid is more easy than when the chloride of silver is quite pure.

The foregoing experiments have given me the most perfect conviction that my estimate of the constitution of hornsilver, deduced from the researches published in my last Essay, is in no wise vitiated by the fact noticed by Dr. Prout. But in order, on a point of so much practical and theoretical interest, not to omit any evidence which might elucidate the subject, I endeavoured to analyse corrosive sublimate by directly ascertaining the quantity of mercury which it contains. For this purpose a quantity of grain tin was oxidized by nitric acid, and the resulting oxide, after being washed and ignited, was reduced by charcoal. The pure tin, after being granulated and washed, was dissolved in strong muriatic acid. The solution was colourless and transparent, and an excess of acid was added to it. The reduction of the bichloride was thus effected. A given weight of the compound was dissolved in a small quantity of hot water acidulated with muriatic acid, and the protochloride of tin, likewise hot, was added in excess. A tube twelve inches long, surrounded by a moist cloth, was then attached to the flask containing the mixture, and ebullition was kept up for a few minutes, the extremity of the tube being closed by the finger. This precaution was taken in order to prevent, as far as possible, loss of mercury by the ebullition which is required for collecting together the finely divided metal. Most of the mercury was thus obtained in one bright globule: it was fully washed by tepid water acidulated with muriatic acid, and the decanted washings were set aside till the suspended particles had subsided. The mercury was ultimately collected on a double filter, which was dried under a bell-jar with a vessel of sulphuric acid, the air at the close being rarified. The two most successful experiments supply the following numbers:—

	1.		2.	
Mercury	44·782	201	73·09	201
Chlorine	15·90	71·366	25·97	71·413.

I should be unwilling to adduce these experiments as giving an exact view of the composition of corrosive sublimate, because the chlorine is inferred from the quantity of mercury collected, and the mercury is obtained by a method in which a small loss is, I believe, unavoidable. They answer the purpose, however, which they were intended to serve. For in giving 35·67 as the equivalent of chlorine, they show the highest practicable number; because, since

the mercury obtained was pure and dry, its quantity could not represent less than was present in the compound subjected to analysis. It may have contained more, but not less mercury than was collected; and any quantity to be added to that above given would proportionally diminish the quantity of chlorine. Thus, if these analyses are at all trustworthy, they prove that the equivalent of chlorine may be less than 35·7, but that it cannot be greater.

There seems, therefore, to be no reason to call in question the methods which have been used to find the equivalent of chlorine. The real number, as above stated, is to be sought within a range extending from 35·28 to 35·45. This range may be much narrowed by facts supplied by other experiments. Were 35·35 assumed as the equivalent of chlorine, 107·78 would be the equivalent of silver, deducible from the composition of chloride of silver; but this number for silver is inconsistent with the analysis of nitrate of silver to be afterwards mentioned, and consequently the hypothesis which led to it is inadmissible. By a similar line of reasoning the equivalent of chlorine may be brought within the limits 35·4 and 35·45. I am disposed to select 35·42 as agreeing closely with my own results, coinciding with the number given in the most recent tables of Berzelius, and as giving a convenient number for silver.

Equivalent of Silver.

It appears, at first sight, such a simple operation to prepare oxide of silver, and to reduce that oxide by heat, that my first attempts to ascertain the atomic weight of silver were made with that compound. It was soon apparent, however, by want of uniformity in my results, that some fallacy existed; and after numerous unsuccessful efforts to detect it, I abandoned the method altogether. The examination of sulphuret of silver was likewise begun, and subsequently abandoned for a similar reason. The analysis of the oxide was thought of as a means of comparing the equivalents of oxygen and chlorine through the medium of silver; but as this object has been attained by other means, it is easy to infer the equivalent of silver by the constitution of the chloride. In the belief that 100 parts of silver unite with 32·8 of chlorine, the atomic weight of silver will be 107·92, 108, or 108·08, according as we adopt 35·4, 35·42, or 35·45, as the equivalent of chlorine. As the whole number has as equal a chance of being correct as either of the others, it may be adopted with propriety, and is certainly a very close approximation.

Equivalent of Barium.

The atomic weight of barium may be calculated from my analysis of the chloride of barium already published in the Philosophical Transactions. According to the proportions there stated, 100 parts of the chloride consist of 65·984 of barium and 34·016 of chlorine; the equivalent of barium is therefore 68·7, that of chlorine being 35·42. The analysis of Berzelius differs slightly from mine, giving 68·53 as the equivalent of barium. I adopt 68·7, as confiding in the indications of frequently repeated experiments; but at present I have no other proof that this number is more exact than that employed by Berzelius; it appears certain that 69 is too high, and that 68 is too low, being incompatible with our analyses.

Equivalent of Nitrogen.

I have endeavoured to ascertain the equivalent of nitrogen by the analysis of the nitrates of silver, lead, and baryta.

Nitrate of Silver.—Pure silver was oxidized and dissolved in nitric acid, and the concentrated hot solution set aside. In cooling, it deposited numerous transparent thin tabular crystals, which were fused, redissolved in water, evaporated, and again kept for some time in a state of fusion. The fused nitrate was quite colourless, and dissolved in water without the least turbidity. It was analysed by solution in water and precipitation by muriatic acid; the whole was transferred to a porcelain capsule, evaporated on the sand-bath to perfect dryness, being protected at the same time from dust and light, and was then fused. The impurity introduced by the acid and water employed in each analysis amounted to 0·01 of a grain, which was subtracted from the whole weight obtained. The following is the result of two very successful analyses, made after several preliminary and less satisfactory experiments:—

	1.			2.		
Nitrate of silver	124·892 grs.	100	118·544	97·992 grs.	100	118·5
Fused chloride of silver	105·355 grs.	84·357	100	82·695 grs.	84·389	100.

It may therefore be inferred, as a mean of these closely corresponding ratios, that 100 parts of the fused chloride corresponds to 118·522 of the fused nitrate of silver. By the analysis of chloride of silver, 100 parts contain 75·3012 of metallic silver, corresponding to 80·87 of oxide, the equivalent of silver being 108.

Hence 118·522 parts of nitrate of silver contain 80·87 of oxide and 37·652 of nitric acid; and on subtracting from this quantity of acid five times the oxygen of the oxide of silver, viz. 27·844, there remain 9·808 of nitrogen. The equivalent of nitrogen, calculated from these numbers, is 14·09.

Nitrate of Lead.—Carefully prepared nitrate of lead was reduced to a very fine powder, and then dried at a temperature of 300°. It is not safe to expose this salt to a temperature much beyond 300° FAHR., as it is apt, when so heated, to suffer partial decomposition: perfect desiccation must be secured by fine levigation, and the continued action of a comparatively moderate heat. Known quantities of the salt were then dissolved in distilled water, and decomposed by an excess of sulphuric acid; and the resulting sulphate was collected in the same manner and with the same precautions as were described in a former part of this Essay, (page 526–528.). The following is the result of three successful experiments:—

	1.		2.		3.	
Nitrate of lead	132 grs.	109·312	99·888 grs.	109·31	130·122 grs.	109·3
Sulphate of lead	120·755 grs.	100	91·38 grs.	100	119·05 grs.	100.

As a mean of these analyses, it follows that 109·307 parts of nitrate yield 100 of sulphate of lead; and it has already been shown that the latter contain 73·575 parts of oxide, and 68·301 of metallic lead. From these data, and by the same mode of reasoning as was applied to nitrate of silver, it follows that 14·201 is the equivalent of nitrogen.

Nitrate of Baryta.—This salt was prepared from the native carbonate, and was purified by repeated crystallization; no impurity could be detected in it, and it was especially examined, by well known tests, for lead and strontia. It was converted into sulphate in the same manner and with the same precautions as were explained in the experiments with lead. It was dried by being reduced to a fine powder, and exposed to a temperature of 500°.

The following is the result of three satisfactorily conducted analyses, performed after several preparatory trials:—

	1.		2.		3.	
Nitrate of baryta	92·83 grs.	112·06	97·38 grs.	111·99	121·391 grs.	112·035
Sulphate of baryta	82·84 grs.	100	86·955 grs.	100	108·35 grs.	100.

As a mean of these analyses it appears that 112·028 parts of nitrate yield 100 of sulphate of baryta, which contain 65·669 of baryta and 58·8195 of

barium. Hence, as in the former instances, it may be calculated that 14·17 is the atomic weight of nitrogen. It is assumed in this calculation that 68·7 is the equivalent of barium, and that 100 parts of chloride of barium contain 65·984 of barium, and correspond to 112·18 of sulphate of baryta.

The equivalent of nitrogen thus appears to be somewhere between the numbers 14·09 and 14·2, and the mean is 14·15, which corresponds closely with the number selected by Berzelius from his analysis of nitrate of lead. It must be admitted, however, that this mode of deducing the equivalent of nitrogen is not a desirable one, since the slightest error in the equivalents of silver, lead, and barium is multiplied five times in estimating the composition of nitric acid. The united testimony of three independent sets of experiments (or rather four, including the analysis of Berzelius,) serves to diminish the force of this objection; but still chemists must give a preference to the more direct method, founded on an exact determination of the densities of oxygen and nitrogen gases, such as we anticipate from the labours of Dr. Prout.

Equivalent of Sulphur.

I have not yet entered upon a systematic investigation of the atomic weight of sulphur, but merely purpose, on the present occasion, to extract the information which flows incidentally out of the researches in which I have been occupied. It has been shown that 100 parts of sulphate of lead consist of 26·425 of sulphuric acid and 73·575 oxide of lead, which last contain 5·274 of oxygen. From these data, coupled with the known atomic constitution of sulphuric acid, it follows that this acid is composed of

Sulphur	10·603 . . .	16·083
Oxygen	15·822 . . .	24
	26·425	40·083

Similarly, from the estimates above given, it follows that 100 parts of sulphate of baryta consist of 34·331 of sulphuric acid and 65·669 of haryta, which contain 6·8495 of oxygen. Hence it follows that sulphuric acid is composed of

Sulphur	13·7825 . . .	16·097
Oxygen	20·5485 . . .	24
	34·3310	40·097.

These estimates agree closely with that of Berzelius, deduced by a similar method. Though in some measure subject to the criticism already referred to in the foregoing observations on nitrogen, they leave no doubt on my mind of the equivalent of sulphur being rather more than exactly double the equivalent of oxygen. I hope, however, to examine this point more narrowly on a future occasion.

Equivalent of Mercury.

The principal experiments which have been published on the equivalent of mercury are by Sefström and Donovan. According to three analyses of the red oxide of mercury by Sefström, the results of which are given in the Annals of Philosophy*, 16 parts of oxygen unite with 202·78, 202·54, 200·24 of mercury. Donovan found the peroxide to consist of 16 parts of oxygen and 204·6 of mercury, and the protoxide of 8 of oxygen and 194·2 of mercury. It is difficult from such very discordant results to strike any mean which should be moderately trustworthy. Donovan's analysis of the protoxide is of no use, as that compound is so very unstable as to be wholly unfit for atomic researches; and his analysis of the peroxide must certainly be erroneous, owing, perhaps, to his having overlooked the presence of metallic mercury in the peroxide which he examined. Even the analyses of Sefström indicate that the equivalent of mercury lies within the somewhat wide range extending from 200·24 to 202·78. The number may be brought within a narrower limit by the researches already described in this Essay. The equivalent deduced from the analyses of the red oxide is 200·94 and 200·93: the three analyses of calomel, taking the atomic weight of chlorine as 35·42, give 201·28, 201·3, and 201·57, of which the mean is 201·38, as the equivalent of mercury; and the numbers deducible from the three analyses of corrosive sublimate are 201·78, 202·16, and 202·18, of which 202·04 is the mean. Thus the equivalent is included within the numbers 200·93 and 202·18. Moreover, it will be remembered, that on calculating the equivalent of chlorine on the hypothesis of 201 being the real equivalent of mercury, an error was committed, which involved the alternative, either that 201 was too low, owing to a slight error in the analysis of the oxide of mercury, or that all the analyses of calomel and

* iii. 355.

corrosive sublimate were inaccurate. The latter supposition is very much less probable than the former. With regard to the relative value of the experiments made with calomel and corrosive sublimate, I rely most on the analyses of the latter, since it is much more stable as regards the action of heat, and hence more certainly obtained in a pure state than calomel. I therefore infer that 202 may be considered as a close approximation to the real equivalent of mercury.

Before closing this communication, I will avail myself of the opportunity to make a few remarks on the employment of filters. In so far, indeed, as respects the experiments which have been described in the present and preceding Essay, the discussion is not very material, since most of the principal facts have been ascertained by processes independent of filtration; but in reference to analysis in general, the subject is very important. In my own researches I am in the habit of determining the weight of substances collected on a filter in one of three different ways. One of these, introduced by Berzelius, consists in burning the filter in a platinum crucible, and deducting the weight of its ashes. This method is peculiarly applicable to the analysis of minerals, where such substances as silica, alumina, and lime are frequent. Even some substances of easy reduction, such as peroxide of iron and sulphate of baryta, may be safely treated in the same way; but in these cases it is advisable not only, as usual, to separate the mass of the precipitate from the filter before setting it on fire, but to moisten both with a little nitric acid, and to ensure very free exposure to the air during the burning of the paper and the subsequent ignition. For such purposes I commonly use some excellent Swedish filtering paper, kindly procured for me by Berzelius.

Another method is that of the double filter, introduced by Dr. Thomson, which I have used in all the experiments where filtration is spoken of in the present and former communication. Both Berzelius and Dr. Thomson himself seem inclined to doubt the accuracy of this method; and it is certainly liable to objection, except with certain precautions and with very compact filtering paper. The paper which I use for the double filter is considerably thicker than the Swedish paper, and of such compact texture that recently precipitated oxalate of lime, or sulphate of baryta thrown down by Glauber's salt in a neutral solution of the chloride of barium, may be filtered by it. The

precautions employed are these. The paper, folded into filters, is macerated in dilute nitric acid for two days, is then fully washed with warm distilled water, and dried at a temperature of about 212° Fahr. After acquiring its hygrometric moisture, two of the filters of nearly the same weight are poised against each other, and any small difference marked in pencil on the lighter one. Before being used, a pin-hole is made in the outer filter, in order that any accidental imperfection in the inner filter should be made apparent. After filtration both filters are dried at the same temperature, and are afterwards allowed to recover their hygrometric moisture completely before removal to the balance. In repeated trials I have found a pair of filters to recover, after use, their original relation in weight to within the 100dth part of a grain; nor have I ever noticed a greater deviation than may well be expected in every process where filtration is concerned. Additional testimony of the same kind will be found in my Essay printed in the Philosophical Transactions for 1819, where, in two sets of experiments, the same point is investigated by the use of double filters and by evaporating the precipitate to dryness without filtration. The series with silver, moreover, are interesting in reference to the remarks of Dr. Prout above noticed (p. 534); for it is manifest from those results that chloride of silver may be collected on paper and dried, (in my experiments the filters were dried in a dark, warm air-closet,) without appreciable loss of acid.

A third method consists in employing a single filter, which is dried before and after filtration at some fixed temperature, as at 212° Fahr.; and when so dried is inclosed in a light silver vessel, the cover of which is tightly fitted by grinding. The filter may thus be deliberately weighed without absorbing moisture during the operation. In case of its being inconvenient to employ an uniform temperature, the filter may be dried at a variable heat, be allowed to absorb hygrometric moisture, and afterwards kept at about 60° Fahr. for two hours in a closed bottle, the bottom of which is covered with pulverized quicklime. In this method, while operating at least with paper of British manufacture, it is essential, more so than with the double filter, to have previously macerated the filter in dilute acid; for all such paper, which I have examined, contains lime.

I now, in conclusion, subjoin a list of the atomic weights ascertained by the researches described in the present communication, and add for the conve-

nience of comparison the corresponding numbers of Berzelius from his latest table of equivalents*, as well as those published by Dr. Thomson in his First Principles of Chemistry.

	Thomson.	Berzelius.	Turner.
Lead	104	103·5598	103·6
Silver	110	108·1285	108
Chlorine	36	35·412	35·42
Barium	70	68·5504	68·7
Mercury	200	202·5315 (Sefström.)	202
Nitrogen	14	14·1628	14·15
Sulphur	16	16·0932	16·09

The equivalents fixed on by Berzelius are in general substantially the same as mine. I have had continual opportunities of witnessing the extreme care which he employs in his experiments, as well as the fairness with which he reports them. His estimates, when directly drawn from his own experiments, are in general very close approximations. The chief difference between us is in the mode of representing equivalents: Berzelius strikes a mean of his results, and then calculates the atomic weight to a number of decimal places, which, in general, far exceed the degree of approximation justified by experiment; whereas I calculate extreme equivalents, and take the mean of them, rejecting all decimals which follow the first doubtful figure. Thus the two last decimals in his equivalent of lead are useless; since the experiments of Berzelius leave it doubtful whether the equivalent of lead may not fall short of 103·55 instead of exceeding that number. This doubt respecting lead again operates on the equivalents of nitrogen and sulphur; so that it is doubtful if the equivalents of these elements may not be smaller instead of greater than 14·16 and 16·09.

With regard to the numbers employed by British chemists, it is apparent that they are in many instances inconsistent with experiment. Numbers asserted to be correct to a minute fraction of a unit, are found in error to the extent of a unit and a half, or two entire units: the equivalent of silver, for instance, instead of being 110, is exactly or nearly 108; and the equivalent of barium has been reduced by Dr. Thomson himself from 70 to 68. The atomic weights

* Poggendorff's Annalen, xxi. 614.

of chlorine and lead are likewise incorrect; and thus are found to be erroneous four quantities which have been employed as elements in calculating the equivalents of nearly all the other elementary substances. Under such circumstances, Dr. Prout's hypothesis, as advocated by Dr. Thomson,—that all atomic weights are simple multiples of that of hydrogen,—can no longer be maintained. I grant most willingly, that a system of whole numbers, considered as moderate approximations, may, with advantage, be retained for the use of medical men, students, and manufacturers; but as the strict representative of scientific truth, applicable to all the purposes of science, this hypothesis is at present untenable. Let me not however be misunderstood: I mean simply to affirm that the experiments by which it has been attempted to prove the truth of this hypothesis are inaccurate: I may go further, and declare it to be not only unsupported by evidence, but to be at variance with the most exact analytic researches which have been conducted. I deny not that some simple relation subsists among atomic weights, and that their ratios may possibly be expressed by some simple series of numbers; but at present no one has assigned any physical cause for the existence of such a relation; no such relation has hitherto been discovered; nor, as appears to me, has analytic chemistry attained that degree of perfection which can justify any one in finally asserting or denying its existence.

XXII. *Note on a Paper by* Dr. John Davy, *entitled "Notice on the remains of the recent Volcano in the Mediterranean." By* Charles Daubeny, *M.D. F.R.S., Professor of Chemistry in the University of Oxford.*

Received May 13,—Read May 16, 1833.

At the request of the Council of the Royal Society, I propose to submit the following remarks on a paper of Dr. John Davy's that has recently been read on the subject of the new volcanic island lately thrown up in the Mediterranean; being desirous of directing the attention of men of science in a more particular manner to the examination of the gases evolved by volcanos, and likewise of pointing out to them certain objections which appear to militate against the hypothesis, by which, in the communication alluded to, the disengagement of nitrogen, accompanied with only half the proportion of oxygen present with it in atmospheric air, is accounted for.

Nitrogen gas has not hitherto, I believe, been often observed to issue from volcanos in action; but the frequent presence of ammoniacal salts amongst the vapours given off by them affords a fair presumption that, if looked for, the gas itself might be found to occur more commonly; especially as the great majority of hot springs—whether such as are immediately and confessedly connected with volcanos, as that of Castella, near Naples, or that more numerous class which are supposed by many geologists (though without such direct evidence,) to owe their temperature to causes of an analogous nature,—copiously evolve it, often in a state of purity, but sometimes, as in the specimen examined by Dr. Davy, intermixed with a certain proportion of oxygen *.

Under such circumstances, the more obvious conclusion would seem to be,

* Having given the details of this subject already, in a paper "On Thermal Waters and their Connexion with Volcanos," published in the Edinburgh New Philosophical Journal, conducted by Professor Jameson, for 1831, I will here only state that the evolution of nitrogen, which was discovered long ago by Dr. Priestley at Bath, and by Dr. Pearson at Buxton, has been lately found by myself

that the evolution of this gas is in some way or other connected with certain chemical processes going on at, or near the place of its occurrence. And in this point of view any account relating to the phenomenon in question derives an interest beyond what it would obtain according to Dr. Davy's mode of considering it, as being calculated in a more especial manner to afford us a clue to the hidden causes of volcanic action in general.

It may therefore not appear irrelevant, if I proceed to point out certain objections that have occurred to me with reference to the latter portion of Dr. Davy's paper; in which nothing more than the mere evolution of the gas is attributed to the volcano itself; whilst the absence of a portion of that oxygen which accompanies it in common air, is resolved into putrefactive processes, going on generally at the bottom of the sea, and therefore wholly unconnected with the particular nature of the locality.

I would observe in the first place, that the notion of sea-water at great depths being wholly or partially deprived of its oxygen by animal putrefaction, &c., seems inconsistent with the general analogy of nature, since in all other cases there appear to be counteracting causes which restore to the air its purity; and that notwithstanding the rapid diminution of light in descending through so dense a medium as water, still the existence, at great depths, of Algæ possessing an intensely green colour would seem to indicate, that the decomposition of carbonic acid is going on there as well as upon land. Indeed, owing to the constant circulation taking place in every mass of water, especially if supposed to rest upon a heated substratum, any influence that might be exerted upon the nature of the air contained would be quickly spread over the whole body of the sea, instead of being limited to its inferior portions, where, moreover, the very existence of animals, which must imbibe this air, leads us to conclude, that no material difference in its quality could obtain.

Granting even the nature of the air contained in sea-water at the bottom of the Mediterranean to be such as Dr. Davy represents, I do not understand

to take place also at Bakewell and Stony Middleton, in Derbyshire, and at Taafe's Well, near Cardiff in South Wales;—that I have likewise detected it issuing from the hot springs of Mont Dor, and Chaudesaigues in central France, and those of St. Gervais, Cormayeur, St. Didier, and Bonneval in Savoy;—and that Longchamp states its occurrence at Vichy and in all the thermal waters at the foot of the Pyrenees. Other instances are mentioned in the paper referred to.

how it can find its way to the surface, in consequence merely of the high temperature to which it is subjected below. Either, in this situation, the pressure of the superincumbent mass of fluid is sufficient to prevent the conversion of the lower strata of water into steam, or it is not. If it be, this same pressure will enable the water to retain in solution its original quantity of air, or at least the greater proportion of it. If, on the contrary, there be not sufficient pressure for the purpose, then no doubt the water will rise up in the form of steam through the superincumbent mass along with the air which it had contained; but as the temperature of the sea round about the volcano, at least near its surface, is stated by Dr. Davy not to be higher than that of the atmosphere, it is plain that all the steam must become rapidly condensed, and when it returns to its liquid state, there seems no reason why it should not exert its affinity for the air intermixed, and combine with it as before.

For these reasons, amongst others, I conceive that the air which Dr. Davy examined cannot have been derived from sea-water, but must have originated from the atmosphere itself, with which this volcano, from its contiguity to Malta and Sicily, may with less difficulty be supposed to communicate; and this is favoured by the probable upheaving of the bed of the Mediterranean underneath the spot at which the island made its appearance; for the proofs of which I may appeal to the memoir of Captain Smyth, lately published in the Transactions, as an Appendix to Dr. Davy's former paper on this subject.

Now the upheaving of the bed of the sea would imply the existence of hollows or caverns underneath, into some of which, if not in immediate connexion with the water above, atmospheric air would doubtless find admission.

I would also observe, that if the quantity of gas emitted bore any proportion, as Captain Swinburne states it did, to that observed in chalybeate springs, so constant a supply could hardly have been derived from such a source as sea-water; for 100 cubic inches of pure distilled water (which holds in solution rather more air than sea-water will do,) only contain about one cubic inch and a half of nitrogen; and in most thermal waters that have been examined, the evolution of this gas is much more copious than it is here represented, and makes its appearance in large and frequent bubbles, and not "in minute silver threads."

In a word, I conceive that Dr. Davy has under-rated the interest which

ought to attach to the information he has afforded respecting the gases given off on the site of this new volcano, by explaining their composition on principles unconnected with volcanic action; whereas a higher importance really attaches to them, if considered, as it appears they ought to be, intimately related to the latter train of effects.

As, however, our estimate of his theory (at least as extended to the case of thermal waters,) may in part depend upon the quantity of gas evolved in a given time, it is to be regretted that no accurate statements of this have as yet, so far as I am aware, been published; and I therefore would invite such men of science as may chance to be conveniently situated for such researches, to examine the volume of gas emitted by some of our own warm springs, as by those at Bath or Buxton; which inquiry, indeed, I hope at some future time to undertake myself, should not the necessity for it be superseded by the previous investigations of others.

XXIII. *Observations of the Comet of Encke, made in June* 1832. *By* Thomas Henderson, *Esq., His Majesty's Astronomer at the Cape of Good Hope. Communicated, by Command of the Lords Commissioners of the Admiralty, by Captain* Beaufort, *R.N., F.R.S., Hydrographer to the Admiralty.*

Received May 17,—Read May 24, 1833.

THE following observations (excepting those with the transit instrument,) were made with a circular micrometer, constructed by Simms, and applied to an achromatic telescope of Dollond, forty-five inches in focal length, and three and a half inches aperture, furnished with a portable equatorial stand, which can be adjusted to any latitude. By means of the horary and declination circles, and the difference of right ascension and declination betwixt the comet and the nearest bright star, the telescope was readily pointed to the comet's place; but when the comet got to the southward of the zenith, and was near the meridian, the equatorial apparatus became useless, as its supports came in the way of the telescope: the telescope was then pointed to the comet according to the best estimate which the eye could make of its place in the heavens relatively to the neighbouring stars. The instrument was placed either at one of the windows of the Observatory building, or out of doors in a corner sheltered from the wind, where the best view of the quarter of the heavens where the comet was situated could be obtained. The magnifying power employed was thirty-two, and the radius of the ring was found to be 1015 seconds of arc.

The transit instrument by Dollond is nearly ten feet in focal length, and the object-glass is five inches in diameter. For observing the comet, an eye-glass, magnifying eighty-eight times (the lowest power which it possesses), was used.

June 2nd.—The times are reckoned according to the chronometer, French, No. 975, which was gaining 13·4 seconds per diem on mean solar time: $9^h\ 44^m\ 12^s$ by the chronometer corresponded to $17^h\ 22^m\ 6^s$ mean time.

The comet was first perceived about $16^h\ 54^m$ mean time, when it had attained an altitude of $6\frac{3}{4}°$ above the horizon, the sun being then 25° below the horizon. It was seen at once on directing the telescope to the position indicated in the Ephemeris.

		Ingress.	Egress.	Comet minus Star.	
				R.	Declination.
		h m s	m s	m s	′ ″
1.	Comet, South....	9 31 16	33 22		
	* *a*, North.....	31 45	33 31	−0 19·5	−18 4
2.	Comet, South....	9 35 4	37 13		
	* *a*, North.....	35 38	37 24	−0 22·9	−17 13
3.	Comet, South....	9 39 1	41 9		
	* *a*, North.....	39 36·5	41 15	−0 21·1	−18 29
4.	Comet, South....	9 43 28	45 36·5		
	* *a*, North.....	44 7	45 43·5	−0 23·3	−18 32
5.	Comet, South....	9 49 8	50 51		
	* *a*, North.....	49 16·5	51 26·5	−0 29·1	−17 14
6.	* *b*, North.....	9 55 44	57 47	+5 23·3	
	* *c*, North.....	10 0 49	1 39	+0 54·0	
	Comet.....	1 1	3 15		
	* *d*, South.....	3 45·5	5 34	−2 32·0	
	* *e*, North.....	5 0·5	6 49	−3 47·4	

The comet appeared as an ill-defined nebulous mass, several minutes in diameter, brighter towards the middle. It seemed as bright as when I saw it on the meridian at Edinburgh, on November 22nd 1828, with an achromatic telescope of thirty inches focal length and two inches aperture; but not nearly so bright as it appeared in the beginning of December of the same year.

Apparent places of the stars.

Stars.	Magnitude.	R.	Declination.
		h m s	° ′ ″
a.....	7	3 43 58·8	−12 28 49
b (π Eridani)....	5	3 38 11·4	12 38 6
c.....	8	3 42 39·2	12 30 43
d.....	8	3 46 5·8	12 57 9
e.....	7	3 47 21·6	12 35 49

June 3rd.—The times are reckoned according to the chronometer, French, No. 975, which was gaining 13·4 seconds per diem on mean solar time: $9^h\ 27^m\ 15^s$ of the chronometer corresponded to $17^h\ 4^m\ 55^s$ mean time.

		Ingress.	Egress.	Comet *minus* Star.	
				Æ.	Declination.
		h m s	m s	m s	′ ″
1.	* *f*, South	9 21 52	23 13·5	+0 23·3	+21 53
	Comet, North	21 54	23 57		
2.	* *f*, South	9 26 14·5	27 42·5	+0 25·9	+22 18
	Comet, North	26 25	28 23		
3.	* *f*, South	9 30 15	31 48	+0 24·8	+21 16
	Comet, North	30 25·5	32 26		

The sky was hazy, and the comet faint. Afterwards clouds came on.

Apparent place of the star.

Star.	Magnitude.	Æ.	Declination.
		h m s	° ′ ″
f	7.8	3 39 7·9	−15 0 21

June 4th.—The times are reckoned by the assistant clock, which was losing 4·7 seconds in the hour on sidereal time: $0^h\ 17^m\ 0^s$ of the clock corresponded to $21^h\ 55^m\ 58^s$ sidereal time.

		Ingress.	Egress.	Comet *minus* Star.	
				Æ.	Declination.
		h m s	m s	m s	′ ″
1.	* *g*, North	0 26 39·5	28 1·5	+0 37·3	− 7 50
	Comet, North	26 52	29 4		
	* *h*, South	29 34	31 8·5	−2 23·3	+18 34
2.	* *g*, North	0 33 35	34 43	+0 38·3	− 8 0
	Comet, North	33 43	35 52		
	* *h*, South	36 18	38 2	−2 22·7	+18 20
3.	* *g*, North	0 39 53·7	40 43	+0 37·4	− 8 17
	Comet, North	39 53	41 59		
	* *h*, South	42 24	44 15·5	−2 23·9	+18 1
4.	* *g*, North	0 46 6	47 35·5	+0 36·1	− 7 52
	Comet, North	46 20	48 34		
	* *h*, South	49 6	50 34·5	−2 23·4	+18 26
5.	* *g*, North	0 52 2·5	53 18	+0 36·6	− 8 24
	Comet, North	52 11	54 23		
	* *h*, South	54 52	56 31	−2 24·6	+18 0
6.	Comet, North	1 1 28	3 39		
	* *i*, North	1 38	3 36·2	−0 3·8	− 3 3
7.	* *g*	1 5 3	6 16	+0 33·4	−11 7
	Comet, North	5 4	7 22		
	* *i*	5 18	7 22	−0 7·2	− 4 44

The comet had nearly the same appearance as on the 2nd.

Apparent places of the stars.

Stars.	Magnitude.	R.	Declination.
		h m s	° ′ ″
g	8	3 34 29·4	−16 30 20
h	8·9	3 37 29·8	16 56 40
i	9	3 35 9·4	16 37 2

June 5th.—The times are reckoned by the assistant clock, which was losing 4·8 seconds in the hour on sidereal time: $1^h\ 4^m\ 0^s$ of the clock corresponded to $22^h\ 47^m\ 43^s{\cdot}5$ sidereal time.

		Ingress.	Egress.	Comet *minus* Star.	
				R.	Declination.
		h m s	m s	m s	′ ″
1.	* *k*, North	0 21 42	23 14	+1 0·0	−17 13
	Comet, South	22 19	24 37		
2.	* *k*, North	0 26 3	27 28·5	+1 0·8	−19 0
	Comet, South	26 39	28 54		
3.	* *k*, North	0 30 24·5	31 41	+0 58·2	−18 32
	Comet, South	30 52	33 10		
4.	* *l*, South	0 35 43	37 18	+1 50·1	+22 40
	Comet, North	37 23	39 18		
5.	* *l*, South	0 40 29	42 12	+1 50·5	+22 32
	Comet, North	42 16	44 6		
6.	* *l*, South	0 46 18	48 8·5	+1 49·2	+22 28
	Comet, North	48 11	49 54		
7.	* *l*, South	0 52 50·5	54 22	+1 49·3	+22 20
	Comet, North	54 26	56 25		

Apparent places of the stars.

Stars.	Magnitude.	R.	Declination.
		h m s	° ′ ″
k	8	3 29 32·0	−18 26 7
l	8	3 28 37·2	19 6 34

On June 6th and 7th the weather prevented any observations being made.

June 8th.—The times are reckoned by the assistant clock, which was losing 2·4 seconds in the hour on sidereal time: $0^h\ 23^m\ 0^s$ of the clock corresponded to $21^h\ 38^m\ 9^s{\cdot}2$ sidereal time.

		Ingress.	Egress.	Comet *minus* Star.	
				Æ.	Declination.
		h m s	m s	m s	′ ″
1.	* *m*, North.....	0 24 53	25 45	+ 2 36·3	−30 9
	Comet, South....	27 15	28 35		
	* *n*, North.....	28 52	31 12·5	− 2 7·1	−20 3
2.	* *m*, North.....	0 32 38·5	33 23·5	+ 2 39·3	−31 19
	Comet, South....	35 7	36 13		
	* *n*, North.....	36 35	38 53·5	− 2 4·0	−21 31
3.	Comet, South....	0 48 18	50 28		
	* *n*, North.....	50 59	52 6·3	− 2 9·6	−23 24
4.	Comet, South....	0 55 28	57 25		
	* *n*, North.....	57 58	59 19·5	− 2 12·1	−24 40
	* *o*, North.....	1 5 38	8 6·5	−10 25·9	
5.	Comet.....	1 11 24	13 47		
	* *o*.....	22 0	24 13	−10 31·3	

Apparent places of the stars.

Stars.	Magnitude.	Æ.	Declination.
		h m s	° ′ ″
m	7	3 12 14·5	−24 44 10
n.....	7·8	3 16 57·6	24 54 3
o.....	7	3 25 11·4	25 11 26

The comet was not again visible till the 23rd, owing partly to the weather, and partly to the moonlight, which obliterated the light of the comet even when the sky was clear.

June 23rd.—The times are reckoned by the assistant clock, which was losing 5·5 seconds in the hour on sidereal time: $1^h\ 53^m\ 0^s$ of the clock corresponded to $1^h\ 6^m\ 8^s{\cdot}5$ sidereal time.

		Ingress.	Egress.	Comet *minus* Star.	
				Æ.	Declination.
		h m s	m s	m s	′ ″
1.	Comet, South....	0 18 25	21 15		
	* *p*, South.....	23 34·5	27 14	− 5 34·0	− 3 27
	* *q*, South.....	26 4	29 40·5	− 8 2·3	− 3 10
	* *r*, North.....	28 34	32 43	−10 48·8	−17 58
2.	Comet, South....	0 39 40	42 20		
	* *p*, South.....	44 36·5	48 35	− 5 35·5	− 6 10
	* *q*, South.....	47 7	51 4·5	− 8 5·7	− 6 1
	* *r*, North.....	49 54	53 48	−10 51·2	−20 53

The comet was much fainter than when last observed. It was not visible in the telescopes of the meridian instruments, the twilight having commenced.

Apparent places of the stars.

Stars.	Magnitude.	R.	Declination.
		h m s	° ′ ″
p	7	0 26 13·9	−59 7 26
q	7·8	0 28 42·9	59 7 48
r	6·7	0 31 29·3	58 53 8

On June 24th and 25th the weather was unfavourable.

June 26th.—The times are reckoned by the assistant clock, which was losing 5·7 seconds in the hour on sidereal time: $1^h\ 31^m\ 0^s$ of the clock corresponded to $0^h\ 56^m\ 59^s$ sidereal time.

	Ingress.	Egress.	Comet *minus* Star.	
			R.	Declination.
	h m s	m s	m s	′ ″
* *s*, North	0 23 30	27 35	+3 17·6	− 3 27
* *t*, North	23 33	28 21	+2 53·1	
* *u*, South	24 27	28 15	+2 29·0	+16 13
Comet, North	26 35	31 5		

The comet was fainter than on the 23rd. It was not seen in the transit telescope as it passed the meridian. It is probable that a mistake was committed in setting the telescope.

Apparent places of the stars.

Stars.	Magnitude.	R.	Declination.
		h m s	° ′ ″
s	7	23 12 29·1	−62 12 36
t	7	23 12 49·0	−62 20 22
u	7	23 13 14·1	−62 32 46

June 27th.—This day's observations are reckoned by a clock of Molyneux, losing 10·6 seconds in the day on mean solar time. At $16^h\ 30^m$ by the clock it was $3^m\ 28^s{\cdot}6$ slow of mean time.

The following observation of the comet's passage through the field of view

of the transit telescope was made by the assistant astronomer, Lieutenant W. Meadows, R.N. Not the slightest illumination could be permitted: the whole room had to be darkened to allow the comet being seen. The wires of the transit instrument were completely invisible.

The comet was not perceived till it had entered the field of view.

At 16 26 12 it was estimated that the comet was in the middle of the field of view.

At 16 30 18 the preceding edge of the comet passed out of the field.

At 16 30 30 the whole was gone.

The telescope was set to 62° 48′ of south declination, and the comet passed along the middle of the field.

The correction of the transit instrument for its deviation from the meridian, at the comet's parallel, was 1·1 second *additive*; and the time employed by an equatorial star in passing from the middle wire till its disappearance from the field is 126·9 seconds of sidereal time, for the eye-glass which was used.

The comet was not seen in the telescope of the mural circle.

		Ingress.	Egress.	Comet *minus* Star.	
				R.	Declination.
		h m s	m s	m s	′ ″
1.	* y.....	16 43 39	48 32	+5 2·6	
	Comet	49 2	53 12		
2.	* w, North.....	17 4 5	6 34	+7 24·4	−22 3
	* x, North.....	3 42	8 29	+6 38·3	−11 20
	* y, South.....	5 38	10 22	+4 43·5	− 2 43
	Comet, South ..	10 32	14 53		

The comet was very faint, and it was very difficult to estimate its centre.

Apparent places of the stars.

Stars.	Magnitude.	R.	Declination.
		h m s	° ′ ″
w	7.8	22 46 15·0	−62 33 47
x.....	7.8	22 47 1·6	62 44 55
y.....	7.8	22 48 55·3	62 52 37

June 28th.—At the comet's meridian transit, it was seen very faintly in the

transit telescope: thin clouds were occasionally passing. The telescope was set to 63° 5′ of south declination. The comet was not detected till it was considerably advanced in the field of the telescope.

Time by transit clock. h	m	s	
22	38	35.	Comet's centre was estimated to go out of the field.
22	39	4.	A star of the 8th magnitude went out of the field.
22	39	32.	Another of the same magnitude went out.

The comet was two or three minutes to the south of the first star.

The transit clock was $1^m\ 17^s{\cdot}5$ fast of sidereal time; and the correction of the instrument and the distance of the extremity of the field from the middle wire were the same as stated yesterday.

The comet was seen still more faintly in Dollond's telescope with the circular micrometer; but owing to its faintness, and the passing clouds, it was impossible to make any observations.

It is to be regretted that the two stars seen in the transit telescope were not identified and observed at the proper season, as they would have afforded an approximation to the comet's declination. It is likely that they will still be observed.

June 29th.—I suspected that I saw the comet in Dollond's telescope; but so extremely faint that any attempt at observation was hopeless. Clouds at meridian transit.

July 6th.—The comet was not visible in the transit telescope at its meridian passage, though the sky was clear. It was no more looked for.

The positions of the stars above given have been determined from observations made in this observatory. The stars *a*, *b*, *c* and *e*, are in Bessel's Zone, No. 271,

	Magn.	t h m s	δ ° ′ ″
a	7	3 43 37·50	− 12 27 42·5
b	5	3 37 50·16	12 37 4·7
c	8	3 42 18·14	12 29 40·1
e	7	3 47 0·50	12 34 41·6

b is π Eridani, No. 415 of the Astronomical Society's Catalogue; *d* is No. 217

and *e* No. 222 of the Constellation Eridanus in Bode's Catalogue; *f* is in Bessel's Zone No. 262, 7.8 magnitude, $t = 3^h\ 39^m\ 33^s{\cdot}98$; $\delta = -14°\ 59'\ 3''{\cdot}6$; *g*, *h*, *i*, *n* and *o* are in the Histoire Céleste Française,

	Magn.	Middle wire. h m s	Zenith distance. ° ′ ″
g, page 478	8	3 33 15·5	65 23 27
h, —— 557	8.9	3 36 16·3	65 49 30
i, —— —	9	3 33 56	65 30 7
n, —— 563	7.8	3 15 53·0	73 47 4
o, —— —	7	3 24 7·4	74 4 5

r is in La Caille's Cœlum Australe Stelliferum, Zone XII. 31st of August 1751, *in parte inferiore reticuli*, 6.7 magnit.

h	m	s
0	22	11
	30	33

In computing the differences of right ascension and declination betwixt the comet and stars, allowance has been made for the comet's motion throughout, and for the effect of refraction for the observations preceding June 23rd. For the observations of that and subsequent days, the effect of refraction has been disregarded, as insensible. The sign + denotes the comet to be more advanced in right ascension than the star, or to the northward of it; the sign − the contrary.

From the observations, the following positions of the comet, cleared of refraction and parallax, have been computed. They are therefore the apparent geocentric places of the comet.

No.	Date.	Mean time.	Æ.	Declination.
	1832.	h m s	h m s	° ′ ″
1	June 2	17 18 31		− 12 46 57
2	„	17 22 6	3 43 35·0	
3	3	17 4 55	3 39 31·1	14 38 46
4	4	17 23 41	3 35 4·2	16 39 19
5	5	17 23 52	3 30 27·5	18 44 28
6	8	16 47 29		25 16 40
7	„	16 53 32	3 14 46·0	
8	23	17 45 4	0 20 38·7	59 12 11
9	26	17 33 36	23 15 44·6	62 16 4
10	27	16 29 21	22 54 14·0	
11	„	17 5 24	22 53 49·2	
12	„	17 16 11		62 55 34
13	28	16 3 56	22 32 41·8	

The positions Nos. 10 and 13 are deduced from the observations of the egress of the comet's centre from the field of the transit telescope; the others, from the observations with the circular micrometer.

Observatory, Cape of Good Hope,
March 8, 1833.

XXIV.—*On the development of the disturbing Function, upon which depend the inequalities of the motions of the Planets, caused by their mutual attraction. By* James Ivory, *K.H., M.A., F.R.S., Instit. Reg. Sc. Paris. Corresp. et Reg. Sc. Gottin. Corresp.*

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THE perturbations of the planets caused by their mutual attraction depend chiefly upon one algebraic expression, from the development of which all the inequalities of their motions are derived. This function is very complicated, and requires much labour and many tedious operations to expand it in a series of parts which can be separately computed according to the occasions of the astronomer. The progress of physical astronomy has undoubtedly been retarded by the excessive length and irksomeness attending the arithmetical calculation of the inequalities. On this subject astronomers generally and continually complain; and that their complaints are well founded, is very aptly illustrated by a paper contained in the last year's Transactions of this Society.

The disturbing function is usually expanded in parts arranged according to the powers and products of the excentricities and the inclinations of the orbits to the ecliptic; and, as these elements are always small, the resulting series decreases in every case with great rapidity. No difficulty would therefore be found in this research, if an inequality depended solely on the quantity of the coefficient of its argument in the expanded function; because the terms of the series decrease so fast, that all of them, except those of the first order, or, at most, those of the first and second orders, might be safely neglected, as producing no sensible variation in the planet's motion. But the magnitude of an inequality depends upon the length of its period, as well as upon the coefficient of its argument. When the former embraces a course of many years, the latter, although almost evanescent in the differential equation, acquires a great multiplier in the process of integration, and thus comes to have a sensible effect on the place of the planet. Such is the origin of some of the most remarkable

of the planetary irregularities, and in particular, of the great equations in the mean motions of Jupiter and Saturn, the discovery of which does so much honour to the sagacity of Laplace. It is not, therefore, enough to calculate the terms of the first order, or of the first and second orders, in the expansion of the disturbing function. This is already done in most of the books that treat of physical astronomy with all the care and fulness which the importance of the subject demands, leaving little room for further improvement. In the present state of the theory of the planetary motions, it is requisite that the astronomer have it in his power to compute any term in the expansion of the disturbing function below the sixth order; since it has been found that there are inequalities depending upon terms of the fifth order, which have a sensible effect on the motions of some of the planets.

A research that has for its object the lessening of the difficulty attending the expansion of the disturbing function, and the bringing of that expression more under the power of the astronomer, is one of considerable interest, and of some moment to the progress of physical astronomy. But the question is not to exhibit separately every individual argument with its coefficient, which would be of little utility in practice, since, although their number be infinite, very few of them are of any account in computing the place of a planet. The end to be aimed at, is to give the function such a form that the astronomer may have it in his power to select any inequality he may wish to examine, and to compute the coefficient of its argument by an arithmetical process of moderate length. The present Paper is an attempt of this kind. The investigation comprehends every argument not passing the fifth order; but, as the formulas are regular, the method may be extended indefinitely to any order.

1. Let x, y, z, represent the rectangular coordinates of the disturbed planet, z being perpendicular to a fixed plane passing through the sun's centre, at which point the origin of the coordinates is placed: in like manner let x', y', z' be the coordinates of the disturbing planet; and put m' for the proportion of the mass of this planet to the sum of the masses of the sun and the disturbed planet; then, R denoting the disturbing function, we shall have,

$$\mathrm{R} = m'\left\{\frac{1}{\sqrt{(x'-x)^2+(y'-y)^2+(z'-z)^2}} - \frac{x\,x'+y\,y'+z\,z'}{(x'^2+y'^2+z'^2)^{\frac{3}{2}}}\right\}.$$

If r and r' denote the distances of the disturbed and disturbing planets from

the sun's centre; ω, their angular distance seen at the same point; and ϱ, their rectilinear distance from one another, then,

$$\varrho = \sqrt{r^2 - 2rr'\cos\omega + r'^2}$$

$$\frac{R}{m'} = \frac{1}{\varrho} - \frac{r\cos\omega}{r'^2}.$$

It appears, therefore, that the function to be expanded consists of two parts, of which $\frac{1}{\varrho}$, the reciprocal of the distance of the two planets, is common to the disturbing functions of both; but this is not the case with the other part, in which r and r' do not enter alike. For this reason it will contribute to distinctness to expand the two parts separately. But, previously, it is necessary to express $\cos\omega$ in terms of the angular motions of the planets in their respective orbits.

If v represent the angular distance of the disturbed planet in its orbit from a fixed origin, and P the place of the node, that is, of the intersection of the orbit with the immoveable plane of xy, P being reckoned in the same plane and from the same origin as v, then $v - P$ will be the angular distance of the planet from the node. Further, if A be the celestial arc between the node and the intersection of the orbits of the two planets, the distance of the planet from the same intersection will be equal to

$$v - P - A.$$

If the foregoing symbols be accented and transferred with like significations to the disturbing planet, the celestial arc between that planet and the intersection of the orbits will be equal to

$$v' - P' - A'.$$

Now $v - P - A$ and $v' - P' - A'$ are two sides of a triangle of which the arc ω is the third side; wherefore if I be the inclination of the two orbits, we shall have

$$\cos\omega = \cos(v - P - A)\cos(v' - P' - A') + \cos I \sin(v - P - A)\sin(v' - P' - A'),$$

or, which is the same thing,

$$\cos\omega = \cos^2\tfrac{1}{2}I \,.\cos(v - v' - P + P' - A + A') + \sin^2\tfrac{1}{2}I \,.\cos(v + v' - P - P' - A - A').$$

Let N be the place of the node of the disturbed planet reckoned in the immoveable plane of $x\,y$, and i the inclination of the orbit to the same plane: then, if ν represent the longitude of the intersection of the orbits of the two planets, A will be the hypothenuse of a right-angled triangle, of which i is one angle, and $\nu - \mathrm{N}$ the side adjacent to i; wherefore

$$\tan \mathrm{A} = \frac{\tan(\nu - \mathrm{N})}{\cos i};$$

and, by the usual methods,

$$\mathrm{A} = \nu - \mathrm{N} + \tan^2 \tfrac{i}{2} \sin 2(\nu - \mathrm{N}) + \tfrac{1}{2} \tan^2 \tfrac{i}{2} \sin 4(\nu - \mathrm{N}), \&c.;$$

and if we put

$$\xi = \tan^2 \tfrac{i}{2} \sin 2(\nu - \mathrm{N}) + \tfrac{1}{2} \tan^2 \tfrac{i}{2} \sin 4(\nu - \mathrm{N}), \&c.,$$

we shall have

$$\mathrm{P} + \mathrm{A} = \nu + \mathrm{P} - \mathrm{N} + \xi.$$

Let $[\mathrm{P} - \mathrm{N}]$ be the value of $\mathrm{P} - \mathrm{N}$ at some given epoch: then the differentials of N and P being $d\mathrm{N}$ and $\cos i \,.\, d\mathrm{N}$, we shall have generally,

$$\mathrm{P} - \mathrm{N} = [\mathrm{P} - \mathrm{N}] - \int d\mathrm{N} + \int \cos i \,.\, d\mathrm{N} = [\mathrm{P} - \mathrm{N}] - 2\int \sin^2 \tfrac{i}{2}\, d\mathrm{N},$$

the integral being taken for the time elapsed from the epoch. It thus appears that $\mathrm{P} - \mathrm{N}$ may be considered as an invariable arc, or as one subject to an almost insensible secular equation. In order to abridge expressions, let us now put

$$\alpha = [\mathrm{P} - \mathrm{N}] - 2\int \sin^2 \tfrac{i}{2}\, d\mathrm{N} + \xi;$$

then

$$\upsilon - \mathrm{P} - \mathrm{A} = \upsilon - \alpha - \nu.$$

If the symbols which stand for the elements of the disturbed planet be assumed, when accented, to represent the like elements of the disturbing planet, we shall have similarly,

$$\alpha' = [\mathrm{P}' - \mathrm{N}'] - 2\int \sin^2 \tfrac{i'}{2}\, d\mathrm{N}' + \xi',$$

$$\upsilon' - \mathrm{P}' - \mathrm{A}' = \upsilon' - \alpha' - \nu.$$

The value of cos ω will now be thus expressed,

$$\cos\omega = \cos^2\frac{1}{2}\mathrm{I}\,.\cos(v - v' - \alpha + \alpha')$$

$$+ \sin^2\frac{1}{2}\mathrm{I}\,.\cos(v + v' - \alpha - \alpha' - 2\nu).$$

It remains to determine I, the inclination of the orbits, and ν, the longitude of their intersection. Now I is the vertical angle of a triangle of which $\mathrm{N} - \mathrm{N}'$ is the base, and i and i' the adjacent angles, one being interior and the other exterior to the triangle: wherefore

$$\cos\mathrm{I} = \cos i\cos i' + \sin i\sin i'\cos(\mathrm{N} - \mathrm{N}').$$

In the same triangle, a perpendicular being let fall upon the base from the vertical angle, $\nu - \mathrm{N}$ and $\nu - \mathrm{N}'$ are the arcs between the perpendicular and the extremities of the base; and hence,

$$\cot\left(\nu - \frac{\mathrm{N} + \mathrm{N}'}{2}\right) = \frac{\sin(i - i')}{\sin(i + i')}\,.\cot\frac{\mathrm{N} - \mathrm{N}'}{2}.$$

In the method here followed, the expression of cos ω is as simple and as little troublesome in calculation, as it would be if one of the orbits were adopted for the immoveable plane.

2. Let ζ, ε, e, ϖ represent the mean motion, the epoch, the excentricity, and the place of the perihelion, of the disturbed planet at the time for which we are computing: if this time be near the epoch for which the elements have been assigned, the values at the epoch may be taken as the true values; and if a great interval has elapsed, the values at the epoch may be corrected by their secular equations. Further, put μ for the mean anomaly, σ for the equation of the centre, a for the mean distance, and $a(1 - s)$ for the radius vector: then,

$$v = \zeta + \varepsilon + \sigma,$$
$$\mu = \zeta + \varepsilon - \varpi,$$
$$\gamma = a(1 - s),$$

And the values of σ and s, found by the solution of Kepler's problem, are expressed by the usual series, viz.

$$\sigma = e \cdot 2\sin\mu \qquad s = e\cos\mu$$

$$+ e^2 \cdot \frac{5\sin 2\mu}{4} \qquad + e^2 \cdot \frac{\cos 2\mu - 1}{2}$$

$$+ e^3 \cdot \frac{13\sin 3\mu - 3\sin\mu}{12} \qquad + e^3 \cdot \frac{3\cos 3\mu - 3\cos\mu}{8}$$

$$+ e^4 \cdot \frac{103\sin 4\mu - 44\sin 2\mu}{96} \qquad + e^4 \cdot \frac{\cos 4\mu - \cos 2\mu}{3}$$

$$+ e^5 \cdot \frac{1097\sin 5\mu - 645\sin 3\mu + 50\sin\mu}{960} \qquad + e^5 \cdot \frac{125\cos 5\mu - 135\cos 3\mu + 10\cos\mu}{384}.$$

Using always the same symbols which stand for the elements of the disturbed planet, when accented, to represent the like elements of the disturbing planet, and introducing the new characters φ and φ' in order to shorten expressions, we shall have,

$$\upsilon - \alpha = \zeta + \varepsilon - \alpha + \sigma = \varphi + \sigma$$
$$\upsilon' - \alpha' = \zeta' + \varepsilon' - \alpha' + \sigma' = \varphi' + \sigma'.$$

If these values, as well the values of r and r', be substituted in that part of the disturbing function which is more easily dealt with, we shall obtain,

$$\frac{r\cos\omega}{r'^2} = \frac{a}{a'^2} \cdot \left\{ \cos^2\frac{1}{2}\mathrm{I} \cdot \cos(\varphi - \varphi' + \sigma - \sigma') \cdot \frac{1-s}{(1-s')^2} \right.$$
$$\left. + \sin^2\frac{1}{2}\mathrm{I} \cdot \cos(\varphi + \varphi' + \sigma + \sigma' - 2\nu) \cdot \frac{1+s}{(1-s')^2} \right\};$$

or,

$$\frac{r\cos\omega}{r'^2} = \frac{a}{a'^2} \cdot \left\{ \cos^2\frac{1}{2}\mathrm{I} \cdot \cos(\varphi - \varphi') \cdot \frac{(1-s)\cos(\sigma - \sigma')}{(1-s')^2} \right.$$
$$- \cos^2\frac{1}{2}\mathrm{I} \cdot \sin(\varphi - \varphi') \cdot \frac{(1-s)\sin(\sigma - \sigma')}{(1-s')^2}$$
$$+ \sin^2\frac{1}{2}\mathrm{I} \cdot \cos(\varphi + \varphi' - 2\nu) \cdot \frac{(1-s)\cos(\sigma + \sigma')}{(1-s')^2}$$
$$\left. - \sin^2\frac{1}{2}\mathrm{I} \cdot \cos(\varphi + \varphi' - 2\nu) \cdot \frac{(1-s)\sin(\sigma + \sigma')}{(1-s')^2} \cdot \right\}$$

The inspecting of this formula is sufficient to show that the expansion of the part multiplied by $\sin^2\frac{1}{2}\mathrm{I}$ is deducible without calculation from the expansion of the other part. For, as σ' is a series of the sines, and s' a series of the cosines, of the multiples of μ', the former will change its sign with μ', while the latter

will not vary: wherefore the expansion of the part multiplied by $\sin^2 \frac{1}{2} I$ will be obtained from the expansion of the other part, merely by making μ' negative, and writing $\varphi + \varphi' - 2\varpi$ in place of $\varphi - \varphi'$ in all the arguments.

We have therefore only to expand the two first lines of the expression, for which purpose they may be thus written:

$$\cos(\varphi - \varphi') \cdot \left\{ (1-s)\cos\sigma \times \frac{\cos\sigma'}{(1-s')^2} + (1-s)\sin\sigma + \frac{(\sin\sigma')}{(1-s')^2} \right\}$$

$$+ \sin(\varphi - \varphi') \cdot \left\{ -(1-s)\sin\sigma \times \frac{\cos\sigma'}{(1-s')^2} + (1-s)\cos\sigma \times \frac{(\sin\sigma')}{(1-s')^2} \right\}$$

Neglecting quantities above the fifth order with respect to the excentricities, we have,

$$(1-s)\cos\sigma = 1 - s - \frac{\sigma^2}{2} + \frac{s\sigma^2}{2} + \frac{\sigma^4}{24} - \frac{s\sigma^4}{24},$$

$$(1-s)\sin\sigma = \sigma - s\sigma - \frac{\sigma^3}{6} + \frac{s\sigma^3}{6} + \frac{\sigma^5}{120};$$

And, if we assume,

$$(1-s)\cos\sigma = A^{(0)} + A^{(1)} e\cos\mu + A^{(2)} e^2\cos 2\mu \ldots + A^{(5)} e^5 \cos 5\mu,$$

$$(1-s)\sin\sigma = B^{(1)} e\sin\mu + B^{(2)} e^2 \sin 2\mu \ldots . B^{(5)} e^5 \sin 5\mu;$$

we shall readily find,

$$A^{(0)} = 1 - \frac{e^2}{2} - \frac{e^4}{64} \qquad B^{(1)} = 2 - \frac{3}{8}e^2 + \frac{5}{96}e^4$$

$$A^{(1)} = -1 - \frac{3}{8}e^2 + \frac{5}{96}e^4 \qquad B^{(2)} = \frac{1}{4} - \frac{5}{12}e^2$$

$$A^{(2)} = \frac{1}{2} - \frac{e^2}{3} \qquad B^{(3)} = \frac{7}{24} - \frac{41}{96}e^2$$

$$A^{(3)} = \frac{3}{8} - \frac{13}{32}e^2 \qquad B^{(4)} = \frac{29}{64}$$

$$A^{(4)} = \frac{67}{129} \qquad B^{(5)} = \frac{77}{240}$$

$$A^{(5)} \frac{17}{48}$$

And, by proceeding similarly,

$$\frac{\cos\sigma'}{(1-s')^2} = a^{(0)} + a^{(1)}.e'\cos\mu' + a^{(2)}.e'^2\cos 2\mu' \ldots + a^{(5)}.e'^5\cos 5\mu'$$

$$\frac{\sin\sigma'}{(1-s')^2} = b^{(1)}.e'\sin\mu' + b^{(2)}.e'^2\sin 2\mu' \ldots + b^{(5)}.e'^5\sin 5\mu'$$

$$a^{(0)} = 1 - \frac{e'^2}{2} - \frac{e'^4}{24} \qquad b^{(1)} 2 - \frac{3}{2}e'^2 + \frac{5}{24}e'^4$$

$$a^{(1)} = 2 - \frac{3}{2}e'^2 + \frac{5}{24}e'^4 \qquad b^{(2)} = \frac{13}{4} - \frac{41}{12}e'^2$$

$$a^{(2)} = \frac{7}{2} - \frac{10}{3}e'^2 \qquad b^{(3)}\frac{31}{6} - \frac{161}{24}e'^2$$

$$a^{(3)} = \frac{11}{2} - \frac{53}{8}e'^2 \qquad b^{(4)} = \frac{761}{96}$$

$$a^{(4)} = \frac{1603}{192} \qquad b^{(5)} = \frac{2827}{240}.$$

$$a^{(5)} = \frac{149}{12}$$

We can now assign any term of the expansion we are considering. Let i and i' be any two positive numbers, zero included, of which the sum does not exceed 5: the part of the expansion multiplied by $e^i e'^{i'} \cos^2\frac{1}{2}\mathrm{I}$ will be,

$$\cos(\varphi - \varphi').\left\{\mathrm{A}^{(i)}a^{(i')}\cos i\mu\cos i'\mu' + \mathrm{B}^{(i)}b^{(i')}\sin i\mu\sin i'\mu'\right\}$$

$$+\sin(\varphi - \varphi').\left\{-\mathrm{B}^{(i)}a^{(i')}\sin i\mu\cos i'\mu' + b^{(i')}\mathrm{A}^{(i)}\sin i'\mu'\cos i\mu\right\}:$$

and, by reduction,

$$\left(\frac{\mathrm{A}^{(i)}a^{(i')} + \mathrm{B}^{(i)}b^{(i')}}{4} - \frac{\mathrm{B}^{(i)}a^{(i')} + b^{(i')}\mathrm{A}^{(i)}}{4}\right).\cos(\varphi - \varphi' - i\mu + i'\mu')$$

$$+\left(\frac{\mathrm{A}^{(i)}a^{(i')} + \mathrm{B}^{(i)}b^{(i')}}{4} + \frac{\mathrm{B}^{(i)}a^{(i')} + b^{(i')}\mathrm{A}^{(i)}}{4}\right).\cos(\varphi - \varphi' + i\mu - i'\mu')$$

$$+\left(\frac{\mathrm{A}^{(i)}a^{(i')} - \mathrm{B}^{(i)}b^{(i')}}{4} - \frac{\mathrm{B}^{(i)}a^{(i')} - b^{(i')}\mathrm{A}^{(i)}}{4}\right).\cos(\varphi - \varphi' - i\mu - i'\mu')$$

$$+\left(\frac{\mathrm{A}^{(i)}a^{(i')} - \mathrm{B}^{(i)}b^{(i')}}{4} + \frac{\mathrm{B}^{(i)}a^{(i')} - b^{(i')}\mathrm{A}^{(i)}}{4}\right).\cos(\varphi - \varphi' + i\mu + i'\mu').$$

The other part of the expansion, that multiplied by $e^{(i)}\, e'^{(i')} \sin^2 \frac{1}{2} \mathrm{I}$, will be different in no respect from the part just computed except in the arguments of the cosines, which must be changed according to the rule already laid down; so that, instead of the four cosines above, these which follow must be substituted respectively,

$$\cos(\varphi + \varphi' - 2\nu - i\mu - i'\mu')$$
$$\cos(\varphi + \varphi' - 2\nu + i\mu + i'\mu')$$
$$\cos(\varphi + \varphi' - 2\nu - i\mu + i'\mu')$$
$$\cos(\varphi + \varphi' - 2\nu + i\mu - i'\mu').$$

Every part of the expansion being comprehended in the formula, it follows that all the arguments will contain the mean motions of the planets, excepting the particular case when $i = 1$, $i' = 1$: for, in this case, $\varphi - \mu$ and $\varphi' - \mu'$ are independent of the mean motions; and the first cosines of the two parts multiplied by $e\,e'$ will be,

$$\cos(\varpi - \varpi' - \alpha + \alpha')$$
$$\cos(\varpi + \varpi' - 2\nu - \alpha - \alpha').$$

These cosines have the same coefficient, viz.

$$\frac{\mathrm{A}^{(i)}\, a^{(i)} + \mathrm{B}^{(i)}\, b^{(i)}}{4} - \frac{\mathrm{B}^{(i)}\, a^{(i)} + \mathrm{A}^{(i)}\, b^{(i)}}{4};$$

And this will be found equal to zero, when the values of the symbols are substituted *. It thus appears, as far as the calculation has been carried, that there are no terms in the expansion of $\frac{r \cos \omega}{r'^2}$ except such as contain the mean motions and are periodical.

3. We next proceed to the expansion of $\frac{1}{\rho}$, which is the more difficult part of the problem. The value of $\cos \omega$, already investigated, may be thus written,

$$\cos \omega = \cos(\varphi - \varphi' + \sigma - \sigma')$$
$$- \sin^2 \tfrac{1}{2} \mathrm{I} \cdot \left\{ \cos(\varphi - \varphi' + \sigma - \sigma') - \cos(\varphi + \varphi' + \sigma + \sigma' - 2\nu) \right\};$$

* The coefficient is equal to zero, because $a^{(i)} = b^{(i)}$: and for the same reason the coefficient

$$\frac{\mathrm{A}^{(i)}\, a^{(i)} - \mathrm{B}^{(i)}\, b^{(i)}}{4} + \frac{\mathrm{B}^{(i)}\, a^{(i)} - b^{(i)}\, \mathrm{A}^{(i)}}{4}$$

is equal to zero.

wherefore,

$$D^2 = r^2 + r'^2 - 2rr' \cos(\varphi - \varphi' + \sigma - \sigma'),$$
$$q = \cos(\varphi - \varphi + \sigma - \sigma') - \cos(\varphi + \varphi' + \sigma + \sigma' - 2\nu),$$
$$\varrho^2 = r^2 + r'^2 - 2rr' \cos\omega = D^2 + 2\sin^2 \tfrac{1}{2} I \cdot rr' q;$$

consequently,

$$\frac{1}{\rho} = \frac{1}{D} - \sin^2 \tfrac{1}{2} I \cdot \frac{rr'}{D^3} q + \tfrac{3}{4} \sin^4 \tfrac{1}{2} I \cdot \frac{r^2 r'^2}{D^5} q^2;$$

and the three parts of $\frac{1}{\rho}$ must be expanded separately.

Expansion of $\frac{1}{D}$.

By substituting $a(1-s)$ and $a'(1-s')$ for r and r', we get

$$\frac{1}{D} = \frac{1}{\sqrt{a^2(1-s)^2 + a'^2(1-s')^2 - 2aa'(1-s)(1-s')\cos(\varphi - \varphi' + \sigma - \sigma')}};$$

and it will be found that the following equation, in partial differentials, is true, viz.

$$\frac{1}{D} = \frac{d \cdot \frac{1}{D}}{ds}(1-s) + \frac{d \cdot \frac{1}{D}}{ds'}(1-s').$$

All the possible values of $\frac{1}{D}$ in this equation are comprehended in the formula,

$$\frac{1}{D} = G \times F;$$

provided F and G verify these equations,

$$G = \frac{dG}{ds}(1-s) + \frac{dG}{ds'}(1-s')$$
$$0 = \frac{dF}{ds}(1-s) + \frac{dF}{ds'}(1-s').$$

We may adopt for G any particular expression which verifies its proper equation; and then F will be determined by the nature of the quantity sought. Any function of $(1-s)$ and $(1-s')$ of -1 dimension will verify the equation for G; and, taking the most simple case, $G = \frac{1}{1-s}$, we shall have

$$\frac{1}{D} = \frac{1}{1-s} \times F.$$

Now let

$$D_0 = \sqrt{a^2 + a'^2 - 2aa'\cos(\varphi - \varphi' + \sigma - \sigma')};$$

then first, if we suppose $s = 0$, $s' = 0$, we get

$$\frac{1}{D} = \frac{1}{D_0};$$

and again, if we suppose $s = s'$, the result will be,

$$\frac{1}{D} = \frac{1}{1-s} \cdot \frac{1}{D_0};$$

and thus we learn that

$$F = \frac{1}{D_0},$$

both when $s = 0$, $s' = 0$, and when $s = s'$. From its equation we know that F must be a function of no dimensions with respect to $(1 - s)$ and $(1 - s')$; and this condition, as well as what has been shown to take place on the two foregoing suppositions, will be fulfilled by making F a function of $\left(1 - \frac{1-s'}{1-s}\right) = \frac{s'-s}{1-s}$: wherefore the expression of $\frac{1}{D}$ will be as follows:

$$\frac{1}{D} = \frac{1}{1-s} \cdot f\left(\frac{s'-s}{1-s}\right),$$

f being the mark of a function which, in the present case, must be equal to $\frac{1}{D_0}$ when $\frac{s'-s}{1-s} = 0$.

Since s and s' are small quantities, the expression of $\frac{1}{D}$ may be expanded. By neglecting quantities above the fifth order with respect to s and s',

$$\frac{1}{D} = \frac{B^{(0)}}{1-s} + B^{(1)} \cdot \frac{s'-s}{(1-s)^2} + B^{(2)} \cdot \frac{(s'-s)^2}{(1-s)^3} \ldots\ldots B^{(5)} \cdot \frac{(s'-s)^5}{(1-s)^6}.$$

In this form it is obvious that all the coefficients may be readily found. For, by differentiating successively with respect to s', and supposing $s = 0$, $s' = 0$, in all the results, we obtain,

$$B^{(0)} = \frac{1}{D_0}, B^{(1)} = \frac{d\frac{1}{D}}{ds'}, B^{(2)} = \frac{1}{1.2} \cdot \frac{d\,d\frac{1}{D}}{ds'^2}, \text{ \&c.}$$

But the expression is complicated; and in order to reduce it to a more ma-

nageable form, every separate term may be resolved into a series of the powers and products of s and s': which being done, and the quantities of the same order classed together, we shall find,

$$\frac{1}{D}=B^{(0)}+B^{(1)}.s' \quad +B^{(2)}s'^2 \quad +B^{(3)}s'^3 \quad +\&c.;$$
$$-\left(B^{(1)}-B^{(0)}\right).s-\left(B^{(2)}-B^{(1)}\right).2ss' \quad -\left(B^{(3)}-B^{(2)}\right).3s'^2s$$
$$+\left(B^{(2)}-2B^{(1)}+B^{(0)}\right)s^2+\left(B^{(3)}-2B^{(2)}+B^{(1)}\right).3s's^2$$
$$-\left(B^{(3)}-3B^{(2)}+3B^{(1)}-B^{(0)}\right).s^3$$

Or, in the usual notation of finite differences,

$$\frac{1}{D}=B^{(0)} \quad +B^{(1)}.s' \quad +B^{(2)}.s'^2 \quad +B^{(3)}s'^3 \quad +B^{(4)}.s'^4 \quad +\&c.;$$
$$-\Delta B^{(0)}.s-\Delta B^{(1)}.2ss'-\Delta B^{(2)}.3s'^2s \quad -\Delta B^{(3)}.4s'^3s$$
$$+\Delta^2B^{0}.s^2 \quad +\Delta^2B^{(1)}.3s's^2 \quad +\Delta^2B^{(2)}.6s'^2s^2$$
$$-\Delta^3B^{0}.s^3 \quad -\Delta^3B^{(1)}.4s's^3$$
$$+\Delta^4B^{(0)}.s^4.$$

The value of $\frac{1}{D}$ seems now to be reduced to its most simple form as far as s and s' are concerned. If it be observed that, in every term, the exponent of the power of s' is the same with the numeral affix of B, and the exponent of s the same with the index of Δ, it will appear that the whole expansion is comprehended in the formula,

$$\Delta^i B^{(i')}.\beta s'^{i'}s^i,$$

β being the coefficient of $s'^{i'}s^i$ in $(s'-s)^{i'+i}$, and i', i, representing the several positive numbers, zero included, of which the sum $(i'+i)$ does not exceed 5, when the expansion is limited to quantities of the fifth order.

4. The values of the quantities $B^{(0)}$, $B^{(1)}$, &c., are next to be investigated. If, for the sake of abridging, we put,

$$Q=a^m(1-s')-a\,a'(1-s)\cos(\varphi-\varphi'+\sigma-\sigma'),$$

we shall get by repeated differentiations,

$$\frac{d\frac{1}{D}}{ds'} = \frac{Q}{D^3},$$

$$\frac{1}{1.2}\cdot\frac{d^2\frac{1}{D}}{ds'^2} = \frac{1}{2}\cdot\frac{dQ}{ds'}\cdot\frac{1}{D^3} + \frac{3}{2}\cdot\frac{Q^2}{D^5},$$

$$\frac{1}{1.2.3}\cdot\frac{d^3\frac{1}{D}}{ds'^3} = \frac{3}{2}\cdot\frac{dQ}{ds'}\cdot\frac{Q}{D^5} + \frac{5}{2}\cdot\frac{Q^3}{D^7},$$

$$\frac{1}{1.2.3.4}\cdot\frac{d^4\frac{1}{D}}{ds'^4} = \frac{3}{8}\cdot\left(\frac{dQ}{ds'}\right)^2\cdot\frac{1}{D^5} + \frac{15}{4}\cdot\frac{dQ}{ds}\cdot\frac{Q^2}{D^7} + \frac{35}{8}\cdot\frac{Q^4}{D^9},$$

$$\frac{1}{1.2.3.4.5}\cdot\frac{d^5\frac{1}{D}}{ds'^5} = \frac{15}{8}\left(\frac{dQ}{ds}\right)^2\cdot\frac{Q}{D^7} + \frac{35}{4}\cdot\frac{dQ}{ds}\cdot\frac{Q^3}{D^9} + \frac{63}{8}\cdot\frac{Q^5}{D^{11}}.$$

Now these expressions become equal to $B^{(1)}$, $B^{(2)}$, &c., when $s' = 0$, $s = 0$, that is, when

$$D = D_0,$$

$$Q = a'^2 - a\,a'\cos(\varphi - \varphi' + \sigma - \sigma') = \frac{D_0^2 + (a'^2 - a^2)}{2},$$

$$\frac{dQ}{ds'} = -a'^2.$$

Let us now put

$$f = a'^2 - a^2, \qquad h = \frac{a'^2 + a^2}{a'^2 - a^2};$$

then,

$$Q = \frac{D_0^2 + f}{2}, \qquad \frac{dQ}{ds} = -f \times \frac{1+h}{2};$$

and, by substituting these values in the foregoing expressions, and reducing, we get

$$B^{(0)} = \frac{1}{D_0}$$

$$B^{(1)} = \frac{1}{2}\left(\frac{1}{D_0} + \frac{f}{D_0^3}\right)$$

$$B^{(2)} = \frac{3}{8}\left(\frac{1}{D_0} + \frac{f^2}{D_0^3}\right) + \frac{2-h}{4}\cdot\frac{f}{D_0^3},$$

$$B^{(3)} = \frac{5}{16}\left(\frac{1}{D_0} + \frac{f^3}{D_0^4}\right) + \frac{9-6h}{16}\left(\frac{f}{D^3} + \frac{f^3}{D^5}\right)$$

$$B^{(4)} = \frac{35}{128}\left(\frac{1}{D_0} + \frac{f^4}{D_0^5}\right) + \frac{20-15h}{32}\left(\frac{f}{D_0^3} + \frac{f^3}{D_0^5}\right) + \frac{6h^2-48h+51}{64}\cdot\frac{f^2}{D_0^5}$$

$$B^{(5)} = \frac{63}{256}\left(\frac{1}{D_0} + \frac{f^5}{D_0^{11}}\right) + \frac{175-140h}{256}\left(\frac{f}{D_0^3} + \frac{f^4}{D_0^5}\right) + \frac{30h^2-150h+135}{128}\cdot\left(\frac{f^3}{D_0^5} + \frac{f^3}{D_0^7}\right).$$

These quantities have been deduced from the differentials $\frac{d\frac{1}{D}}{ds}$, $\frac{1}{1.2}\cdot\frac{dd\frac{1}{D}}{ds^2}$, &c. If the differentials $\frac{d\frac{1}{D}}{ds}$, $\frac{1}{1.2}\cdot\frac{dd\frac{1}{D}}{ds^2}$, &c., be used, the same results will be found, with this difference, that f and h, retaining the same numerical values, will both change their signs.

If we write ψ for $(\varphi - \varphi' + \sigma - \sigma')$ and differentiate the formula,

$$\frac{d\frac{1}{D_0^n}}{d\psi} = -n\cdot\frac{a\,a'\sin\psi}{D_0^{n+2}},$$

the result will be,

$$\frac{dd\frac{1}{D_0^n}}{d\psi^2} = -n\cdot\frac{a\,a'\cos\psi}{D_0^{n+2}} + n.n+2\cdot\frac{a^2\,a'^2\sin^2\psi}{D_0^{n+4}};$$

now,

$$a\,a'\cos\psi = \frac{a'^2+a^2}{2} - \frac{D_0^2}{2},$$

$$a'^2\,a^2\sin^2\psi = -\frac{D_0^4}{4} + \frac{a'^2+a^2}{2}\cdot D_0^2 - \frac{(a'^2-a^2)^2}{4};$$

wherefore,

$$\frac{dd\frac{1}{D_0^n}}{d\psi^2} = -\frac{n^2}{4}\cdot\frac{1}{D_0^n} + \frac{n.n+1}{2}\cdot\frac{a'^2+a^2}{D_0^{n+2}} - \frac{n.n+2}{4}\cdot\frac{(a'^2-a^2)^2}{D_0^{n+4}};$$

whence we deduce

$$\frac{f^3}{D_0^{n+4}} = -\frac{4}{n.n+2}\cdot\frac{dd\frac{1}{D_0^n}}{d\psi^2} - \frac{n}{n+2}\cdot\frac{1}{D_0^n} + \frac{2(n+1)}{n+2}h\cdot\frac{f}{D_0^{n+2}}.$$

In this formula put n successively equal to 1, 3, 5, 7; then

$$\frac{f^3}{D_0^5} = -\frac{4}{3}\cdot\frac{dd\frac{1}{D_0}}{d\psi^2} - \frac{1}{3}\cdot\frac{1}{D_0} + \frac{4h}{3}\cdot\frac{f}{D_0^3},$$

$$\frac{f^3}{D_0^7} = -\frac{4}{15}\cdot\frac{dd\frac{f}{D_0^3}}{d\psi^2} - \frac{3}{5}\cdot\frac{f}{D_0^3} + \frac{8h}{5}\cdot\frac{f^2}{D_0^5},$$

$$\frac{f^4}{D_0^9} = -\frac{4}{35}\cdot\frac{dd\frac{f^2}{D_0^5}}{d\psi^2} - \frac{5}{7}\cdot\frac{f^2}{D_0^5} + \frac{12h}{7}\cdot\frac{f^3}{D_0^7},$$

$$\frac{f^5}{D_0^{11}} = -\frac{4}{63}\cdot\frac{dd\frac{f^3}{D_0^7}}{d\psi^2} - \frac{7}{9}\cdot\frac{f^3}{D_0^7} + \frac{16h}{9}\cdot\frac{f^4}{D_0^9}.$$

By means of the two first of these last formulas, we can exterminate $\frac{f^2}{D_0^5}$ and $\frac{f^3}{D_0^7}$ from the values of $B^{(2)}$ and $B^{(3)}$; which being done, we shall find

$$B^{(2)} = \left(\frac{1}{4}\cdot\frac{1}{D_0} - \frac{1}{2}\cdot\frac{dd\frac{1}{D_0}}{d\psi^2}\right) + \frac{2+h}{4}\cdot\frac{f}{D_0^3},$$

$$B^{(3)} = \left(\frac{3-h}{24}\cdot\frac{1}{D_0} - \frac{9+2h}{12}\cdot\frac{dd\frac{1}{D_0}}{d\psi^2}\right) + \left(\frac{4h^2+9h+9}{24}\cdot\frac{f}{D_0^3} - \frac{1}{12}\cdot\frac{dd\frac{f}{D_0^3}}{d\psi^2}\right).$$

And, in like manner, by means of all the four formulas, we may exterminate $\frac{f^2}{D_0^5}$, $\frac{f^3}{D_0^7}$, $\frac{f^4}{D_0^9}$ and $\frac{f^5}{D_0^{11}}$, from the expressions of $B^{(4)}$ and $B^{(5)}$; and thus are obtained these values,

$$B^{(4)} = -\frac{3h^2+8h-7}{96}\cdot\frac{1}{D_0} + \frac{3h^2+8h^2+8h+6}{24}\cdot\frac{f}{D_0^3}$$

$$-\frac{12h^2+32h+77}{96}\cdot\frac{dd\frac{1}{D_0}}{d\psi^2} - \frac{1}{6}\cdot\frac{dd\frac{f}{D_0^3}}{d\psi^2} - \frac{1}{32}\cdot\frac{dd\frac{f^2}{D_0^5}}{d\psi^2},$$

$$B^{(5)} = -\frac{24h^3+75h^2+92h-55}{960}\cdot\frac{1}{D_0} + \frac{96h^4+300h^3+341h^2+200h+159}{960}\cdot\frac{f}{D_0^3}$$
$$-\frac{96h^3+300h^2+368h+725}{960}\cdot\frac{dd\frac{1}{D_0^3}}{d\psi^2} - \frac{12h^2+221}{960}\cdot\frac{dd\frac{f}{D_0^3}}{d\psi^2}$$
$$-\frac{25-4h}{320}\cdot\frac{dd\frac{f^2}{D_0^5}}{d\psi^2} - \frac{1}{64}\cdot\frac{dd\frac{f^3}{D_0^7}}{d\psi^2}.$$

If we take the second differentials relatively to ψ in the first two of the same four formulas, we shall obtain these values of $\frac{dd\frac{f^2}{D_0^5}}{d\psi^2}$ and $\frac{dd\frac{f^3}{D_0^7}}{d\psi^2}$, viz.

$$\frac{dd\frac{f^2}{D_0^5}}{d\psi^2} = -\frac{4}{3}\cdot\frac{d^4\frac{1}{D_0}}{d\psi^4} - \frac{1}{3}\cdot\frac{dd\frac{1}{D_0}}{d\psi^2} + \frac{4h}{3}\cdot\frac{dd\frac{f}{D_0^3}}{d\psi^2},$$
$$\frac{dd\frac{f^3}{D_0^7}}{d\psi^2} = -\frac{4}{15}\cdot\frac{d^4\frac{f}{D_0^3}}{d\psi^4} - \frac{32h}{15}\cdot\frac{d^4\frac{1}{D_0}}{d\psi^4} - \frac{8h}{15}\cdot\frac{dd\frac{1}{D_0}}{d\psi^2} + \frac{32h^2-9}{15}\cdot\frac{dd\frac{f}{D_0^3}}{d\psi^2};$$

which being substituted, the expressions of $B^{(4)}$ and $B^{(5)}$ will be as follow:

$$B^{(4)} = -\frac{3h^3+8h-7}{96}\cdot\frac{1}{D_0} - \frac{3h^3+8h+19}{24}\cdot\frac{dd\frac{1}{D_0}}{d\psi^2} + \frac{1}{24}\cdot\frac{d^4\frac{1}{D_0}}{d\psi^4}$$
$$+\frac{3h^3+8h^2+8h+6}{24}\cdot\frac{f}{D_0^3} - \frac{h+4}{24}\cdot\frac{dd\frac{f}{D_0^3}}{d\psi^2}.$$

$$B^{(5)} = \left\{-\frac{24h^3+75h^2+92h-55}{960}\cdot\frac{1}{D_0} - \frac{24h^3+75h^2+91h-175}{240}\cdot\frac{dd\frac{1}{D_0}}{d\psi^2}\right.$$
$$\left.+\frac{25+4h}{240}\cdot\frac{d^4\frac{1}{D_0}}{d\psi^4}\right\}$$
$$+\left\{\frac{96h^4+300h^3+341h^2+200h+159}{960}\cdot\frac{f}{D_0^3} - \frac{7h^2+25h+53}{240}\cdot\frac{dd\frac{f}{D_0^3}}{d\psi^2}\right.$$
$$\left.+\frac{1}{240}\cdot\frac{d^4\frac{f}{D_0^3}}{d\psi^4}\right\}.$$

Thus the six quantities $B^{(0)}$, $B^{(1)}$, &c., are all expressed in terms of $\frac{1}{D_0}$

and $\frac{f}{D_0^3}$, and the second and fourth differentials of the same two quantities, the coefficients being of easy computation, and depending solely on the mean distances of the two planets.

5. The problem to be solved is, to expand $\frac{1}{D}$ in a series of terms arranged according to the cosines of the arc ψ, or $\varphi - \varphi' + \sigma - \sigma'$, and its successive multiples. Now as the quantities $\frac{1}{D_0}$ and $\frac{f}{D_0^3}$ and their differentials, are all susceptible of a like development, what is required will be accomplished merely by substituting in $B^{(0)}$, $B^{(1)}$, &c., the parts of $\frac{1}{D_0}$, $\frac{f}{D_0^3}$, and their differentials, multiplied by the cosine of the same multiple of ψ, instead of the quantities themselves. The coefficients of the cosines in the developments in question are functions of $\frac{a}{a'}$ or $\frac{a'}{a}$; and, for the sake of convergency, we must choose that one of the two fractions which is less than unit. Supposing that a' is greater than a, and that n represents any odd number, we have,

$$\frac{f^{\frac{n-1}{2}}}{D_0^n} = \frac{\left(1 - \frac{a^2}{a'^2}\right)^{\frac{n-1}{2}}}{a'} \times \frac{1}{\left\{1 + \frac{a^2}{a'^2} - 2\frac{a}{a'}\cos\psi\right\}^{\frac{n}{2}}}.$$

Wherefore, assuming as usual,

$$\frac{1}{\left\{1 + \frac{a^2}{a'^2} - 2\frac{a}{a'}\cos\psi\right\}^{\frac{n}{2}}} = \tfrac{1}{2}C_n^{\,0} + C_n^{\,(1)}\cos\psi + C_n^{\,(2)}\cos 2\psi \ldots + C_n^{\,(k)}\cos k\psi \ldots,$$

the part of $\frac{1}{D_0}$, and of its second and fourth differentials, which are multiplied by $\cos k\psi$, will be respectively,

$$\frac{\cos k\psi}{a'} \times C_1^{\,(k)}, \frac{\cos k\psi}{a'} \times -k^2 C_1^{\,(k)}, \frac{\cos k\psi}{a'} \times k^4 C_1^{\,(k)};$$

and the like parts of $\frac{f}{D_0^3}$ and its differentials, will be,

$$\frac{1 - \frac{a^2}{a'^2}}{a'} \times C_3^{\,(k)}\cos k\psi, \frac{1 - \frac{a^2}{a'^2}}{a'} \times -k^2 C_3^{\,(k)}\cos k\psi, \frac{1 - \frac{a^2}{a'^2}}{a'} \times k^4 C_3^{\,(k)}\cos k\psi.$$

It remains then to substitute these values in $B^{(0)}$, $B^{(1)}$, &c., in place of $\frac{1}{D_0}$, $\frac{f}{D_0^3}$, and their differentials: but, in order to obtain the formulas most convenient for calculation, it will be requisite to express the coefficient of the development of $\frac{f}{D_0^3}$ by means of those of the development of $\frac{1}{D_0}$.

If we write α for $\frac{a}{a'}$, and put

$$V = \sqrt{1 + \alpha^2 - 2\alpha\cos\psi},$$

we have this formula,

$$\frac{d.\frac{1}{V}}{d\psi} = -\frac{\alpha\sin\psi}{V^3};$$

and if we substitute the expansions of $\frac{1}{V}$ and $\frac{1}{V^3}$, and equate the coefficients of $\sin k\psi$, the result will be

$$2k\,C_1^{(k)} = \alpha\,C_3^{(k-1)} - \alpha\,C_3^{(k-1)}.$$

We have likewise this identical expression,

$$\frac{1}{V} = \frac{V^2}{V^3} = \frac{1+\alpha^2}{V^3} - \frac{2\alpha\cos\psi}{V^3};$$

and by substituting the expansions of $\frac{1}{V}$ and $\frac{1}{V^3}$, and equating the coefficients of $\cos k\psi$, we get

$$C_1^{(k)} = (1+\alpha^2)\,C_3^{(k)} - \alpha\,C_3^{(k-1)} - \alpha\,C_3^{(k+1)}.$$

By combining the two formulas, we deduce

$$2\alpha\,C_3^{(k+1)} = (1+\alpha^2)\,C_3^{(k)} - (2k+1)\,C_1^{(k)}$$
$$2\alpha\,C_3^{k-1} = (1+\alpha^2)\,C_3^{(k)} - (2k-1)\,C_1^{(k)}.$$

Change k for $k-1$ in the first of these formulas, and for $k+1$ in the second, and the two following formulas will be obtained,

$$2\alpha\,C_3^{(k)} = (1+\alpha^2)\,C_3^{k-1} - (2k-1)\,C_1^{(k-1)}$$
$$2\alpha\,C_3^{(k)} = (1+\alpha^2)\,C_3^{(k+1)} + (2k+1)\,C_1^{k+1}.$$

By combining the four last formulas in different ways, different values of $C_3^{(k)}$ will be found, which may be used at pleasure, viz.

$$(1-\alpha^2)\,C_3^{(k)} = (2k+1)\,.\left\{\frac{1+\alpha^2}{1-\alpha^2}\,C_1^{(k)} - \frac{2\alpha}{1-\alpha^2}\,.\,C_1^{(k+1)}\right\}$$

$$(1-\alpha^2)\,C_3^{(k)} = (2k-1)\,.\left\{\frac{2\alpha}{1-\alpha^2}\,C_1^{(k-1)} - \frac{1+\alpha^2}{1-\alpha^2}\,C_1^{(k)}\right\}$$

$$(1-\alpha^2)\,C_3^{(k)} = \frac{4k^2-1}{4k}\,.\,\frac{2\alpha}{1-\alpha^2}\,.\left(C_1^{k-1} - C^{k+1}\right).$$

In order to shorten expressions, and to bring the formulas to a form convenient for calculation, let

$$\alpha = \tan\tfrac{1}{2}\theta\,;$$

then,

$$\frac{1+\alpha^2}{1-\alpha^2} = h = \frac{1}{\cos\theta},\ \frac{2\alpha}{1-\alpha^2} = \frac{\sin\theta}{\cos\theta} = h\sin\theta:$$

further, assume the new symbol $a^{(k)}$, the value of which may be calculated by any one of these formulas, viz.

$$a^{(k)} = (2k+1)\,.\left(C_1^{k} - \sin\theta\,C_1^{(k+1)}\right),$$

$$a^{(k)} = (2k-1)\,.\left(\sin\theta\,C_1^{(k-1)} - C_1^{(k)}\right),$$

$$a^{(k)} = \frac{4k^2-1}{4k}\,.\,\sin\theta\left(C_1^{k-1} - C_1^{k+1}\right);$$

then,

$$(1-\alpha^2)\,C_3^{(k)} = h\,.\,a^{(k)}.$$

Using this value, the parts of $\frac{f}{D_0^3}$ and its differentials, multiplied by $\cos k\psi$ will be

$$\frac{\cos k\psi}{a'} \times h\,a^{(k)},\ \frac{\cos k\psi}{a'} \times -hk^2\,a^{(k)},\ \frac{\cos k\psi}{a'} \times h\,k^4\,a^k.$$

These, as well as the like parts of $\frac{1}{D^0}$ and its differentials, must be substituted in $B^{(0)}$, $B^{(1)}$, &c. As there is no longer occasion to refer to any development but one, C^k may be written for $C_1^{(k)}$. In substituting we omit the common factor $\frac{\cos k\psi}{a'}$, and put

$$b_0^{(k)},\ b_1^{(k)},\ b_2^{(k)} \ldots\ldots b_5^{(k)}$$

for the expressions into which

$$B^{(0)}, B^{(1)}, B^{(2)} \ldots\ldots B^{(5)}$$

are changed, so that,

$$b_0^{(k)} = C^{(k)}$$

$$b_1^{(k)} = \tfrac{1}{2}\, C^{(k)} + \tfrac{h}{2} \cdot a^{(k)},$$

$$b_2^{(k)} = \left(\tfrac{1}{4} + \tfrac{1}{2} k^2\right) C^{(k)} + \frac{h^2 + 2h}{4} \cdot a^{(k)},$$

$$b_3^{(k)} = \left(\frac{3-h}{24} + \frac{9+2h}{12} \cdot k^2\right) \cdot C^{(k)} + \left(\frac{4h^3 + 9h^2 + 9h}{24} + \frac{h}{12} k^2\right) \cdot a^{(k)},$$

$$b_4^{(k)} = \left(-\frac{3h^2 + 8h - 7}{96} + \frac{3h^2 + 8h + 19}{24} \cdot k^2 + \frac{k^4}{24}\right) \cdot C^{(k)}$$
$$+ \left(\frac{3h^4 + 8h^3 + 8h^2 + 6h}{24} + \frac{h^2 + 4h}{24} \cdot k^2\right) \cdot a^{(k)},$$

$$b_5^{(k)} = \left(-\frac{24h^3 + 75h^2 + 92h - 55}{960} + \frac{24h^3 + 75h^2 + 91h + 175}{240} \cdot k^2 + \frac{25 + 4h}{240} \cdot k^4\right) \cdot C^{(k)}$$
$$+ \frac{(96h^5 + 300h^4 + 341h^3 + 200h^2 + 159h}{960} + \frac{7h^3 + 25h^2 + 53h}{240} k^2 + \frac{h k^4}{240}\Big) \cdot a^{(k)}.$$

And, these symbols being established, the part of $\frac{1}{D}$ we are in search of, that is, the part multiplied by $\cos k(\varphi - \varphi' + \sigma - \sigma')$, will be thus expressed,

$$\frac{\cos k(\varphi - \varphi' + \sigma - \sigma')}{a'} \times$$

$$\Big\{ b_0^{(k)} + b_1^{(k)} \cdot s^1 + b_2^{(k)} \cdot s^2 + b_3^{(k)} \cdot s^3 + b_4^{(k)} \cdot s^4 + b_5^{(k)} \cdot s^5$$
$$- \Delta b_0^{(k)} \cdot s - \Delta b_1^{(k)} \cdot 2s^1 s - \Delta b_2^{(k)} \cdot 3s^2 s - \Delta b_3^{(k)} \cdot 4s^3 s - \Delta b_4^{(k)} \cdot 5s^4 s$$
$$+ \Delta^2 b_0^{(k)} \cdot s^2 + \Delta^2 b_1^{(k)} \cdot 3s^1 s^2 + \Delta^2 b_2^{(k)} \cdot 6s^2 s^2 + \Delta^2 b_3^{(k)} \cdot 10 s^3 s^2$$
$$- \Delta^3 b_0^{(k)} \cdot s^3 - \Delta^3 b_1^{(k)} \cdot 4s^1 s^3 - \Delta^3 b_2^{(k)} \cdot 10 s^2 s^3$$
$$+ \Delta^4 b_0^{(k)} \cdot s^4 + \Delta^4 b_1^{(k)} \cdot 5s^1 s^4$$
$$- \Delta^5 b_0^{(k)} \cdot s^5.$$

By the foregoing analysis the problem is reduced to a series of terms comprehended in the formula,

$$\pm \Delta^{i} b_{i'}^{(k)} \times \beta s'^{i'} s^{i} \cos k(\varphi - \varphi' + \sigma - \sigma')$$

i' and i representing all positive numbers, zero included, of which the sum $i' + i$ does not exceed 5; β standing for the coefficient of $s'^{i'} s^{i}$ in $(s' + s)^{i'+i}$; and the upper or lower sign taking place according as the index of Δ is even or odd. Although all the coefficients are supposed to be deduced from six of them, for which alone direct expressions are given, it is nevertheless obvious that an independent formula may be found by which any proposed coefficient may be separately computed: namely, by substituting the values of $b_0^{(k)}$, $b_1^{(k)}$, &c., in the expressions of the several finite differences.

Although there can be no difficulty in applying the formulas, it may not be improper, for the sake of illustration, to take an example. We shall choose the instance of

Venus and the Earth.

In this case a' will represent the mean distance of the Earth, and a that of Venus: wherefore,

$$\frac{a}{a'} = \alpha = 0{\cdot}7323332 = \tan \tfrac{1}{2}\theta, \quad \theta = 71^\circ\ 45'\ 32'',$$

$$h = \frac{1}{\cos \theta} = 3{\cdot}1947202, \quad \log. \sin \theta = 9{\cdot}9776083.$$

The method likewise requires that there be previously calculated a sufficient number of the first coefficients in the expansion,

$$\frac{1}{\sqrt{1 + \alpha^2 - 2\alpha \cos \psi}} = \tfrac{1}{2} C^{(0)} + C^{(1)} \cos \psi + C^{(2)} \cos 2\psi \ldots . C^{(k)} \cos k\psi \ldots .,$$

which is accomplished by rules amply detailed in all the treatises on Physical Astronomy. We next deduce the value of $a^{(k)}$, viz.

$$a^{(k)} = (2k + 1) \cdot \left(C^{(k)} - \sin \theta\, C^{(k+1)} \ldots\right):$$

and, with the numbers thus found, we have generally for any proposed value of k,

$$b_0^{(k)} = C^{(k)},$$

$$b_1^{(k)} = \tfrac{1}{2} C^{(k)} + 1{\cdot}59736 \,.\, a^{(k)}$$

$$b_2^{(k)} = \left(\tfrac{1}{4} + \tfrac{k^2}{2}\right) . C^{(k)} + 4{\cdot}148919 \,.\, a^{(k)}$$

$$b_3^{(k)} = \{-0{\cdot}008113 + 1{\cdot}282453 \,.\, k^2\} . C^{(k)}$$
$$+ \{10{\cdot}459698 + 0{\cdot}266227\, k^2\} . a^{(k)}$$

$$b_4^{(k)} = \left\{-0{\cdot}512255 + 3{\cdot}132352\, k^2 + \frac{k^4}{24}\right\} . C^{(k)}$$
$$+ \{28{\cdot}09035 + 0{\cdot}957713\, k^2\} . a^{(k)}$$

$$b_5^{(k)} = \{-1{\cdot}861383 + 8{\cdot}390554\, k^2 + 0{\cdot}157412\, k^4\} . C^{(k)}$$
$$+ \{80{\cdot}06813 + 2{\cdot}719660\, k^2 + {\cdot}0133113\, k^4\} . a^{(k)}$$

Nothing can be more easy than the computation of these six quantities for any assigned value of k. The other quantities, being the several orders of the finite differences of the first six, will be known when these have been computed: but it will be convenient and will often save much calculation to have an independent formula for every coefficient separately.

$$-\Delta b_0^{(k)} = \tfrac{1}{2} C^{(k)} - 1{\cdot}59736 \,.\, a^{(k)}$$

$$-\Delta b_1^{(k)} = \left(\tfrac{1}{4} - \tfrac{k^2}{2}\right) C^{(k)} - 2{\cdot}551559 \,.\, a^{(k)}$$

$$-\Delta b_2^{(k)} = \{0{\cdot}258113 - 0{\cdot}782453\, k^2\} . C^{(k)}$$
$$- \{6{\cdot}31078 + 0{\cdot}266227\, k^2\} . a^{(k)}$$

$$-\Delta b_3^{(k)} = \left\{0{\cdot}504142 - 1{\cdot}849899\, k^2 - \frac{k^4}{24}\right\} C^{(k)}$$
$$- \{17{\cdot}63065 + 0{\cdot}691486\, k^2\} . a^{(k)}$$

$$-\Delta b_4^{(k)} = \{1{\cdot}34913 - 5{\cdot}258202\,k^2 - 0{\cdot}115745\,k^4\}\,C^{(k)}$$
$$- \{51{\cdot}97778 + 1{\cdot}761947\,k^2 + {\cdot}0133113\,k^4\}\,a^{(k)}$$

$$\Delta^2 b_0^{(k)} = \left(\tfrac{1}{4} + \frac{k^2}{2}\right) C^{(k)} + 0{\cdot}954199\,a^{(k)}$$

$$\Delta^2 b_1^{(k)} = \{-\,{\cdot}008113 + {\cdot}282453\,k^2\}\,C^{(k)}$$
$$+ \{3{\cdot}75922 + {\cdot}266227\,k^2\}\,a^{(k)}$$

$$\Delta^2 b_2^{(k)} = \{-\,{\cdot}24603 + 1{\cdot}067446\,k^2 + {\cdot}041667\,k^4\}\,C^{(k)}$$
$$+ \{11{\cdot}31987 + 0{\cdot}425259\,k^2\}\,a^{(k)}$$

$$\Delta^2 b_3^{(k)} = \{-\,{\cdot}84499 + 3{\cdot}408303\,k^2 + {\cdot}074078\,k^4\}\,C^{(k)}$$
$$+ \{34{\cdot}34714 + 1{\cdot}070461\,k^2 + {\cdot}0133113\,k^4\}\,a^{(k)}$$

$$-\Delta^3 b_0^{(k)} = \{0{\cdot}25811 + {\cdot}217547\,k^2\}\,C^{(k)}$$
$$- \{2{\cdot}80502 + {\cdot}266227\,k^2\}\,a^{(k)}$$

$$-\Delta^3 b_1^{(k)} = \{{\cdot}23792 - {\cdot}784993\,k^2 - {\cdot}041667\,k^4\}\,C^{(k)}$$
$$- \{7{\cdot}56065 + {\cdot}159032\,k^2\}\,a^{(k)}$$

$$-\Delta^3 b_2^{(k)} = \{{\cdot}59896 - 2{\cdot}340857\,k^2 - {\cdot}032411\,k^4\}\,C^{(k)}$$
$$- \{23{\cdot}02727 + {\cdot}645158\,k^2 + {\cdot}013113\,k^4\}\,a^{(k)}$$

$$\Delta^4 b_0^{(k)} = \{{\cdot}020197 + 1{\cdot}002540\,k^2 + {\cdot}041667\,k^4\}\,C^{(k)}$$
$$+ \{4{\cdot}75563 - {\cdot}107195\,k^2\}\,a^{(k)}$$

$$\Delta^4 b_1^{(k)} = \{-\,{\cdot}36104 + 1{\cdot}555864\,k^2 - {\cdot}009256\,k^4\}\,C^{(k)}$$
$$+ \{15{\cdot}46662 + {\cdot}486126\,k^2 + {\cdot}0133113\,k^4\}\,a^{(k)}$$

$$-\Delta^5 b_0^{(k)} = \{{\cdot}38124 - {\cdot}553324\,k^2 + {\cdot}050923\,k^4\}\,C^{(k)}$$
$$- \{10{\cdot}71099 + {\cdot}593321\,k^2 + {\cdot}0133113\,k^4\}\,a^{(k)}.$$

According to these formulas the calculation of any of the coefficients is an easy arithmetical process. In order to be able to compute, in any term of the

expansion of $\frac{1}{D}$, the part of any proposed order with respect to e and e', nothing more is wanting than a method for reducing

$$\beta s^{i'} s^{i} \cos(\varphi - \varphi' + \sigma - \sigma')$$

to a series of simple cosines. On this point some observations will be offered below: but, without proceeding further, there is no difficulty in this respect, when we confine our views to quantities not passing the second or third order, which comprehends all the perturbations useful in astronomy, except the inequalities of very long periods.

If we combine the planets two and two, as is done in the sixth chapter of the sixth book of the Mécanique Céleste, and for every two planets construct a formula such as is exhibited above for Venus and the Earth, limiting the extent of the calculation according to the nature of the case, the theory of the planetary disturbances would be rendered more accessible, and would be freed from the tedious and disgusting labour which has rendered astronomers averse from cultivating this branch of their science.

6. The expression,

$$s^{i'} s^{i} \cos k(\varphi - \varphi' + \sigma - \sigma')$$

may be reduced to this form,

$$\cos k(\varphi - \varphi') \cdot \left\{ (s^{i} \cos k\sigma)(s^{i'} \cos k\sigma') + (s^{i} \sin k\sigma)(s^{i'} \sin k\sigma') \right\}$$

$$- \sin k(\varphi - \varphi') \cdot \left\{ (s^{i} \sin k\sigma)(s^{i'} \cos k\sigma') - (s^{i} \cos k\sigma)(s^{i'} \sin k\sigma') \right\}.$$

Here the quantities within the brackets are serieses, of which each contains the mean anomaly of only one planet, and comes under one or other of eleven different forms, namely, the six,

$$\cos k\sigma,\ s \cos k\sigma,\ s^2 \cos k\sigma,\ \ldots\ldots\ s^5 \cos k\sigma,$$

and the five,

$$\sin k\sigma,\ s \sin k\sigma,\ s^2 \sin k\sigma,\ \ldots\ldots\ s^4 \sin k\sigma,$$

the quantity $s^5 \sin k\sigma$, which is of the sixth order, being omitted. None of these serieses, when carried to quantities of the fifth order inclusively, and arranged according to the sines and cosines of the multiples of the mean anomaly, con-

tain more than six terms, and they thus afford a ready way of calculating the part of

$$s^{i'} s^{i} \cos k\,(\varphi - \varphi' + \sigma - \sigma')$$

of any proposed order with respect to e and e'.

These serieses are as follow:

$$\begin{aligned}
\mathrm{Cos}\, k\sigma = {} & \left(1 - k^2 e^2 - \frac{9}{64} k^2 e^4 + \frac{k^4 e^4}{4}\right) \\
& - \left(\frac{5}{4} k^2 e^2 + \frac{1}{16} k^2 e^4 - \frac{5}{12} k^4 e^4\right) . e \cos \mu \\
& + \left(k^2 - \frac{4}{3} k^2 e^2 - \frac{k^4 e^2}{3}\right) . e^2 \cos 2\mu \\
& + \left(\frac{5}{4} k^2 - \frac{27}{16} k^4 e^2 - \frac{5}{8} k^4 e^2\right) . e^3 \cos 3\mu \\
& + \left(\frac{k^4}{12} + \frac{283}{192} k^2\right) . e^4 \cos 4\mu \\
& + \left(\frac{5 k^4}{24} + \frac{7 k^5}{4}\right) . e^5 \cos 5\mu .
\end{aligned}$$

$$\begin{aligned}
\mathrm{Sin}\, k\sigma = {} & \left(2k - \frac{k e^2}{4} + \frac{5 k e^4}{96} - k^3 e^2 + \frac{13 k^3 e^4}{96} + \frac{k^5 e^5}{6}\right) . e \sin \mu \\
& + \left(\frac{5k}{4} - \frac{11 k e^2}{24} - \frac{5 k^3 e^3}{4}\right) . e^2 \sin 2\mu \\
& + \left(\frac{13 k}{24} - \frac{43}{64} k e^2 - \frac{k^3}{3} - \frac{307 k^3 e^2}{192} - \frac{k^4 e^4}{12}\right) . e^3 \sin 3\mu \\
& + \left(\frac{103}{96} k + \frac{5}{8} k^3\right) . e^4 \sin 4\mu \\
& + \left(\frac{1097}{960} k + \frac{179}{192} k^3 + \frac{k^5}{60}\right) . e^5 \sin 5\mu .
\end{aligned}$$

$$\begin{aligned}
s \cos k\sigma = {} & - \frac{e^2}{2} + \frac{k^2 e^4}{8} \\
& + \left(1 - \frac{3 e^2}{8} + \frac{5 e^4}{192} - \frac{k^2 e^2}{2} + \frac{37 k^2 e^4}{96} + \frac{k^4 e^4}{12}\right) . e \cos \mu \\
& + \left(\frac{1}{2} - \frac{e^2}{3} - k^2 e^2\right) . e^2 \cos 2\mu
\end{aligned}$$

$$+\left(\frac{3}{8}-\frac{45\,e^2}{128}+\frac{k^2}{2}-\frac{183\,.\,k^2\,e^2}{128}-\frac{k^4\,e^2}{8}\right).e^3\cos 3\,\mu$$

$$+\left(\frac{1}{3}+\frac{7\,k^2}{8}\right).e^4\cos 4\,\mu$$

$$+\left(\frac{125}{384}+\frac{475}{384}\,k^2+\frac{k^4}{24}\right).e^5\cos 5\,\mu$$

$$s\sin k\,\sigma=-k\left(\frac{7}{8}\,e^2-\frac{3}{32}\,e^4-\frac{5\,k^2\,e^2}{24}\right).e\sin\mu$$

$$+k\left(1-\frac{23}{24}\,e^2-\frac{k^2\,e^2}{3}\right).e^2\sin 2\,\mu$$

$$+k\left(\frac{9}{8}-\frac{115\,.\,e^2}{96}-\frac{35\,k^2\,e^2}{48}\right).e^3\sin 3\,\mu$$

$$+\left(\frac{59}{48}\,k+\frac{k^3}{6}\right).e^4\sin 4\,\mu$$

$$+\left(\frac{11}{8}\,k+\frac{19}{48}\,k^3\right).e^5\sin 5\,\mu$$

$$s^2\cos k\,\sigma=\frac{e^2}{2}-\frac{k^2\,e^4}{4}$$

$$-\left(\frac{e^2}{2}-\frac{e^4}{24}+\frac{k^2\,e^4}{8}\right).e\cos\mu$$

$$+\left(\frac{1}{2}-\frac{e^2}{2}\right).e^2\cos 2\,\mu$$

$$+\left(\frac{1}{2}-\frac{9\,e^2}{16}-\frac{7\,k^2\,e^2}{16}\right).e^3\cos 3\,\mu$$

$$+\left(\frac{1}{2}+\frac{k^2}{4}\right).e^4\cos 4\,\mu$$

$$+\left(\frac{25}{48}+\frac{9\,k^2}{16}\right).e^5\cos 5\,\mu$$

$$s^2\sin k\,\sigma=\left(\frac{k\,e^2}{2}+\frac{k\,e^4}{12}-\frac{k^3\,e^4}{12}\right).e\sin\mu$$

$$-\frac{3\,k\,e^2}{8}.e^2\sin 2\,\mu$$

$$+\left(\frac{k}{2}-\frac{5\,k\,e^2}{6}-\frac{k^3\,e^2}{12}\right).e^3\sin 3\,\mu$$

$$+\frac{13k}{16}\,.\,e^4\sin 4\mu$$

$$+\left(\frac{13k}{12}+\frac{k^3}{12}\right).\,e^5\sin 5\mu$$

$$s^3\cos k\sigma = -\frac{3}{8}e^4$$

$$+\left(\frac{3}{4}e^2-\frac{3e^4}{16}+k^2e^4\right).\,e\cos\mu$$

$$+\left(\frac{1}{4}-\frac{9e^2}{32}+\frac{k^2e^2}{8}\right).\,e^3\cos 3\mu$$

$$+\frac{3}{8}\,.\,e^4\cos 4\mu$$

$$+\left(\frac{15}{32}+\frac{k^2}{8}\right).\,e^5\cos 5\mu$$

$$s^3\sin k\sigma = -\frac{7ke^4}{16}\,.\,e\sin\mu\;+\frac{ke^2}{2}\,.\,e^2\sin 2\mu\;+\frac{3ke^3}{32}\,.\,e^3\sin 3\mu$$

$$+\frac{k}{2}\,.\,e^4\sin 4\mu\;+\frac{17k}{32}\,.\,e^5\sin 5\mu$$

$$s^4\cos k\sigma = \frac{3}{8}e^4-\frac{e^4}{2}\,.\,e\cos\mu+\frac{e^2}{2}\,.\,e^2\cos 2\mu+\frac{e^2}{4}\,.\,e^3\cos 3\mu$$

$$+\frac{1}{8}\,.\,e^4\cos 4\mu+\frac{1}{4}\,.\,e^5\cos 5\mu$$

$$s^4\sin k\sigma = \frac{ke^4}{4}\,.\,e\sin\mu+\frac{3ke^3}{8}\,.\,e^3\sin 3\mu+\frac{1}{8}\,.\,e^5\sin 5\mu$$

$$s^5\cos k\sigma = \frac{5e^4}{8}\,.\,e\cos\mu+\frac{5e^2}{16}\,.\,e^3\cos 3\mu+\frac{1}{16}\,e^5\cos 5\mu$$

The use of these serieses is obvious. If we wish to determine all the arguments of the order $e^x e'^{x'}$ in the term multiplied by $\cos k(\varphi-\varphi'+\sigma-\sigma')$, of the development of $\frac{1}{D}$, x and x' representing two positive integer numbers, zero included, of which the sum does not exceed 5; we first set aside all the parts of

the expression in which i is greater than x, or i' greater than x', for these contain no quantities of the order $e^{x} e'^{x'}$. Let

$$\Delta^{i} b_{\varphi}^{(k)} \times \beta s^{i} s'^{i'} \cos k(\varphi - \varphi' + \sigma - \sigma')$$

be one of the remaining parts, in which i is not greater than x, nor i' greater than x'; in the serieses $s^{i} \cos k\sigma$ and $s^{i} \sin k\sigma$, take the terms $A e^{x} \cos x\mu$ and $B e^{x} \sin x\mu$; and, in $s'^{i'} \cos k\sigma'$ and $s'^{i'} \sin k\sigma'$, take the terms $A' e'^{x'} \cos x'\mu'$ and $B' e'^{x'} \sin x'\mu'$; then all the arguments of the order $e^{x} e'^{x'}$ will be contained in the formula

$$\Delta^{i} b_{\varphi}^{(k)} \times \beta e^{x} e'^{x'} \times$$

$$\cos k(\varphi - \varphi') \,.\, \{A A' \cos x\mu \cos x'\mu' + B B' \sin x\mu \sin x'\mu'\}$$
$$- \sin k(\varphi - \varphi') \,.\, \{A' B \sin x\mu \cos x'\mu' - A B' \cos x\mu \sin x'\mu'\}.$$

And thus are computed all the quantities of the order $e^{x} e'^{x'}$ in any term of the development of $\frac{1}{D}$. The procedure is exactly the same with that followed in the expansion of the first part of the disturbing function in § 2. All the arguments of the order $e^{x} e'^{x'}$ are only four, comprehended in the formula

$$k(\varphi - \varphi') \pm x\mu \pm x'\mu',$$

which represents all the different ways of combining $x\mu$ and $x'\mu'$, by addition and subtraction, with $k(\varphi - \varphi')$. Hence it is easy to ascertain the orders of the same argument, or the relative magnitude of its coefficients, as it recurs in different terms of the development of $\frac{1}{D}$.

7. We have next to consider the parts of the disturbing function which depend on the inclination of the orbits.

Development of $\sin^2 \frac{1}{2} I \,.\, \frac{r r'}{D^3} \,.\, q.$

Omitting quantities above the third order with respect to s and s' in the expression of $\frac{1}{D}$ found in § 3, we have

$$\frac{1}{D} = B^{(0)} + B^{(1)} s' + B^{(2)} s'^2 \quad + B^{(3)} s'^3$$
$$- \Delta B^{(0)} s - \Delta B^{(1)} 2 s s' - \Delta B^{(2)} 3 s s'^2$$
$$+ \Delta^2 B^{(0)} s^2 \quad + \Delta^2 B^{(1)} 3 s^2 s'$$
$$- \Delta^3 B^{(0)} s^3.$$

As the values of $B^{(0)}$, $B^{(1)}$, &c., contain $\frac{1}{D_0}$ and its powers, they may be regarded as functions of $\cos \psi$: taking the differentials with regard to this variable, we get,

$$\frac{d B^{(0)}}{d(\cos\psi)} = \frac{a a'}{D_0^3} = \frac{a a'}{f} \times \frac{f}{D_0^3} = \frac{a a'}{f} \times B'^{(0)},$$

$$\frac{d B^{(1)}}{d(\cos\psi)} = \frac{a a'}{f} \left(\frac{1}{2} \cdot \frac{f}{D_0^3} + \frac{3}{2} \cdot \frac{f^3}{D_0^5} \right) = \frac{a a'}{f} \times B'^{(1)},$$

$$\frac{d B^{(2)}}{d(\cos\psi)} = \frac{a a'}{f} \left(\frac{3}{8} \frac{f}{D_0^3} + \frac{6 - 3h}{4} \cdot \frac{f^3}{D_0^5} + \frac{15}{8} \cdot \frac{f^3}{D_0^7} \right) = \frac{a a'}{f} \times B'^{(2)},$$

$$\frac{d B^{(3)}}{d(\cos\psi)} = \frac{a a'}{f} \times \left(\frac{5}{16} \cdot \frac{f}{D_0^3} + \frac{27 - 18h}{16} \cdot \frac{f^3}{D_0^5} + \frac{45 - 30h}{16} \cdot \frac{f^3}{D_0^7} + \frac{35}{16} \cdot \frac{f^4}{D_0^9} \right)$$
$$= \frac{a a'}{f} \times B'^{(3)}.$$

If we now differentiate the above formula for $\frac{1}{D}$, and observe that

$$\frac{a a'}{f} = \frac{a a'}{a^2 - a^2} = \frac{1}{2\sqrt{h^2 - 1}} = \frac{\tan \frac{\theta}{2}}{2},$$

the result, when the new symbols are introduced, will be as follows:

$$\frac{r r'}{D^3} = \frac{\tan. \frac{\theta}{2}}{2} \times \Big\{ B'^{(0)} + B'^{(1)} s' \quad + B'^{(2)} s'^2 \quad + B'^{(3)} s'^3$$
$$- \Delta B'^{(0)} s - \Delta B'^{(1)} . 2 s s' - \Delta B'^{(2)} 8 s s'^2$$
$$+ \Delta^2 B'^{(0)} s^2 \quad + \Delta^2 B'^{(1)} 3 s^2 s'$$
$$- \Delta^3 B'^{(0)} s^3.$$

The values of $B'^{(0)}, B'^{(1)}$, &c., may be reduced to expressions that contain only $\frac{1}{D_0}$ and $\frac{f}{D_0^3}$ and their second and fourth differentials, by the same process that was applied to $B^{(0)}, B^{(1)}$, &c., in § 4: and in this manner we obtain,

$$B'^{(0)} = \frac{f}{D_0^3}$$

$$B'^{(1)} = -\frac{1}{2} \cdot \frac{1}{D_0} - 2\,\frac{d\,d\,\frac{1}{D_0}}{d\psi^2} + \frac{4h+1}{2} \cdot \frac{f}{D_0^3},$$

$$B'^{(2)} = -\frac{3h+2}{4} \cdot \frac{1}{D_0} - (3h+2) \cdot \frac{d\,d\,\frac{1}{D_0}}{d\psi^2}$$

$$+\left(3h^2+2h-\frac{3}{4}\right) \cdot \frac{f}{D_0^3} - \frac{1}{2} \cdot \frac{d\,d\,\frac{f}{D_0^3}}{d\psi^2}$$

$$B'^{(3)} = -\frac{24h^2+27h+1}{24} \cdot \frac{1}{D_0} - \frac{48h^2+54h+1}{12} \cdot \frac{d\,d\,\frac{1}{D_0}}{d\psi^2} + \frac{1}{3} \cdot \frac{d^4\,\frac{1}{D_0}}{d\psi^4}$$

$$+\frac{96h^3+108h^2-23h-33}{24} \cdot \frac{f}{D_0^3} - \frac{10h+9}{12} \cdot \frac{d\,d\,\frac{f}{D_0^3}}{d\psi^2}.$$

The term multiplied by $\cos k\psi$ in the expansion of $\frac{rr'}{D^3}$, will now be obtained by substituting in $B'^{(0)}, B'^{(1)}$, &c., the parts of $\frac{1}{D_0}, \frac{f}{D_0^3}$, and their differentials, multiplied by the same cosine. Let

$$\frac{\cos k\psi}{a'} \times b'^{(k)}_0, \frac{\cos k\psi}{a'} \times b'^{(k)}_1, \frac{\cos k\psi}{a'} \times b'^{(k)}_2, \frac{\cos k\psi}{a'} \times b'^{(k)}_3,$$

denote the expressions into which

$$B'^{(0)}, B'^{(1)}, B'^{(2)}, B'^{(3)},$$

are changed by the substitutions mentioned; the quantity sought, or the part of the expansion of $\sin^2 \frac{1}{2} I \times \frac{rr'}{D^3} \times q$ multiplied by $\cos k\psi$, will be thus expressed,

$$\frac{\sin^2 \frac{1}{2} \mathrm{I} \,.\, \cos k\,(\varphi - \varphi' + \sigma - \sigma') \times q}{a'} \times$$

$$\frac{\tan \frac{\theta}{2}}{2} \,.\, \Big\{ b_0^{(k)} + b_1^{(k)}\, s' + b_2^{(k)}\, s'^2 + b_3^{(k)}\, s'^3$$

$$- \Delta b_0^{(k)}\, s - \Delta b_1^{(k)}\, 2\, s s' - \Delta b_2^{(k)}\, 3\, s s'^2$$

$$+ \Delta b_0^{(k)}\, s^2 \quad + \Delta^2 b_1^{(k)}\, 3\, s^2 s'$$

$$- \Delta^3 b_0^{(k)}\, s^3 :$$

and the values of $b_0^{(k)}$, $b_1^{(k)}$, &c., will be as follow:

$$b_0^{(k)} = h \,.\, a^{(k)},$$

$$b_1^{(k)} = (-\tfrac{1}{2} + 2\,k^2)\, \mathrm{C}^{(k)} + \frac{4\,h^2 + h}{2} \,.\, \mathrm{a}^{(k)}$$

$$b_2^{(k)} = (3\,h\,2) \,.\, \frac{4\,k^2 - 1}{4} \,.\, \mathrm{C}^{(k)} + \Big(3\,h^2 + 2\,h^2 \tfrac{3}{2}\,h + \frac{h}{2} \,.\, k^2\Big) \,.\, \mathrm{a}^{(k)}$$

$$b_3^{(k)} = \Big\{ -\frac{24\,h^2 + 27\,h + 1}{24} + \frac{48\,h^2 + 54\,h + 1}{12} \,.\, k^2 + \frac{k^4}{3} \Big\} \,.\, \mathrm{C}^{(k)}$$

$$+ \Big\{ \frac{96\,h^4 + 108\,h^3 - 23\,h^2 - 33\,h}{24} + \frac{10\,h^2 + 9\,h}{12}\, k^2 \Big\} \,.\, \mathrm{a}^{(k)}.$$

By taking the several orders of the finite differences of these four quantities, the other six coefficients may be numerically computed, or an independent formula may be found for calculating each of the six separately. The expansion of this part of the disturbing function is therefore reduced to the expressing of

$$\beta\, s'^{i'} s^i \cos k\,(\varphi - \varphi + \sigma - \sigma') \times q$$

in a series of simple cosines, i' and i being any positive numbers, zero included, the sum of which, $i' + i$, does not exceed 3, and β being the coefficient of $s'^{i'} s^i$ in $(s' + s)^{i' + i}$. By substituting what q stands for, we have,

$$s'^{i'} s^i \cos k\,(\varphi - \varphi' + \sigma - \sigma') \times q$$

$$= \tfrac{1}{2}\, s'^{i'} s^i \cos (k - 1)\,(\varphi - \varphi' + \sigma - \sigma')$$

$$+ \tfrac{1}{2}\, s'^{i'} s^i \cos (k + 1)\,(\varphi - \varphi' + \sigma - \sigma')$$

$$-\tfrac{1}{2}s^{i'}s^{i}\cos(\overline{k-1}\,.-\varphi\overline{k+1}\,.\varphi'-2\nu+\overline{k-1}\,.\sigma-\overline{k+1}\,.\sigma')$$
$$-\tfrac{1}{2}s^{i'}s^{i}\cos(k+1\,.\varphi-\overline{k-1}\,.\varphi'-2\nu+\overline{k+1}\,.\sigma-\overline{k-1}\,.\sigma').$$

As the arguments in the expansions of these four terms are different, each term must be computed separately, for which purpose the method in § 6 may be used. Thus

$$s^{i'}s^{i}\cos(\overline{k-1}\,.\varphi-\overline{k+1}\,.\varphi'-2\nu+\overline{k-1}\,.\sigma-\overline{k+1}\,.\sigma')$$
$$=\cos(\overline{k-1}\,.\varphi-\overline{k+1}\,.\varphi'-2\nu).\Big\{\Big(s^{i}\cos(k-1).\sigma\Big)\Big(s^{i'}\cos(k+1)\sigma'\Big)$$
$$+\Big(s^{i}\sin(k-1)\sigma\Big).\Big(s^{i'}\sin(k+1)\sigma'\Big)\Big\}$$
$$-\sin(\overline{k-1}\,.\varphi-\overline{k+1}\,.\varphi'-2\nu).\Big\{\Big(s^{i}\sin(k-1)\sigma\Big).\Big(s^{i'}\cos(k+1)\sigma'$$
$$-\Big(s^{i}\cos(k-1)\sigma\Big).\Big(s^{i'}\sin(k+1)\sigma'\Big)\Big\};$$

and the quantities within the brackets being known serieses, the part of the expansion of any order $e^{i}e^{i'}$, is readily obtained.

8. One part of the disturbing function yet remains to be considered.

Expansion of $\sin^4\tfrac{1}{2}\mathrm{I}\times\frac{s^2}{2}\cdot\frac{r^2r'^2}{\mathrm{D}^5}\times q^0$.

In the expression of $\frac{rr'}{\mathrm{D}^3}$ found in § 7, leave out quantities of the second and third order with respect to s and s', and we shall have,

$$\tfrac{1}{2}\cdot\frac{rr'}{\mathrm{D}^3}=\frac{\tan.\vartheta}{\varrho}\times\Big\{\tfrac{1}{2}\mathrm{B}^{(0)}+\tfrac{1}{2}\mathrm{B}^{(1)}.e'\cos\mu'$$
$$-\tfrac{1}{2}\Delta\mathrm{B}^{0}.e\cos\mu.$$

Now let

$$\tfrac{1}{2}\cdot\frac{d\,\mathrm{B}^{(0)}}{d(\cos\psi)}=\frac{a\,a'}{f'}\cdot\tfrac{3}{4}\frac{f^3}{\mathrm{D}_0^{\,5}}=\frac{a\,a'}{f'}\times\mathrm{B}''^{(0)}$$

$$\tfrac{1}{2}\cdot\frac{d\,\mathrm{B}^{(1)}}{d(\cos\psi)}=\frac{a\,a'}{f'}\Big(\tfrac{3}{4}\cdot\frac{f^2}{\mathrm{D}_0^{\,5}}+\frac{15}{4}\cdot\frac{f^3}{\mathrm{D}_0^{\,7}}\Big)=\frac{a\,a'}{f'}\times\mathrm{B}''^{(1)};$$

and differentiate the formula for $\frac{1}{2}\cdot\frac{rr'}{\mathrm{D}^3}$ relatively to the variable $\cos\psi$, intro-

ducing the new symbols, and observing that $\frac{a\,a'}{f} = \frac{\tan\frac{\theta}{2}}{2}$, the result will be,

$$\tfrac{3}{2}\cdot\frac{r^2\,r'^2}{D^5} = \frac{\tan^2\frac{\theta}{2}}{4}\times\left\{B^{(i)(0)} + B^{(i)(1)}\,e'\cos\mu'\right.$$
$$\left. - \Delta B^{(i)0}\,e\cos\mu.\right.$$

The quantities $B^{(i)(0)}$ and $B^{(i)(1)}$, when expressed as before in terms of $\frac{1}{D_0}$ and $\frac{f}{D_0^3}$ and their differentials, will be as follow:

$$B^{(i)(0)} = \tfrac{3}{8}\cdot\frac{f^2}{D_0^5} = -\tfrac{1}{2}\cdot\frac{1}{D_0} - 2\,\frac{d\,d\frac{1}{D_0}}{d\psi^2} + 2\,h\cdot\frac{f}{D_0^3},$$

$$B^{(i)(1)} = \tfrac{3}{4}\cdot\frac{f^2}{D_0^5} + \frac{15}{4}\cdot\frac{f^3}{D_0^7} =$$
$$-(8\,h+1)\cdot\left(\tfrac{1}{2}\cdot\frac{1}{D_0} + \frac{d\,d\frac{1}{D_0}}{d\psi^2}\right) - (8\,h^2 + h - \tfrac{9}{4})\cdot\frac{f}{D_0^3} - \frac{d\,d\frac{f}{D_0^3}}{d\psi^2}.$$

Proceeding as before, let

$$\frac{\cos k\,\psi}{a'}\times b^{(i)(k)}_0, \text{ and } \frac{\cos k\,\psi}{a'}\times b^{(i)(k)}_2,$$

represent the expressions into which

$$B^{(i)(0)} \text{ and } B^{(i)(1)}$$

are changed, when we substitute, instead of $\frac{1}{D_0}$ and $\frac{f}{D_0^3}$ and their differentials, the parts of these quantities multiplied by $\cos k\,\psi$: then the part multiplied by $\cos k\,\psi$ in the expansion of $\sin^4\frac{1}{2}\,I \times \frac{3}{8}\,\frac{r^2\,r'}{D^5}\times q^2$, will be thus expressed:

$$\frac{\sin^4\frac{1}{2}\,I\times\cos k\,(\phi - \phi' + \sigma - \sigma')\times q^2}{a'}\times$$
$$\frac{\tan^2\frac{\theta}{2}}{4}\times\left\{b^{(i)(k)}_0 + b^{(i)(k)}_1\cdot e\cos\mu'\right.$$
$$\left. - \Delta\, b^{(i)(k)}_0\, e\cos\mu;\right.$$

and the values of $b^{(i)(k)}_0$ and $b^{(i)(k)}_1$ will be as follow:

$$b^{(i)(k)}_0 = \frac{4\,k^2-1}{2}\,C^{(k)} + 2\,h^2\cdot a^{(k)},$$

$$b^{(i)(k)}_1 = (8\,h+1)\,\frac{4\,k^2-1}{4}\cdot C^{(k)} + \left\{8\,h^3 + h^2 - \frac{9}{4}\,h + h\,k^2\right\}\cdot a^{(k)}.$$

The coefficients for any proposed value of k may now be readily computed; and nothing is wanting in this part of the problem but to reduce the factor,

$$\cos k(\varphi - \varphi' + \sigma - \sigma'). \left\{ \cos(\varphi - \varphi + \sigma - \sigma') - \cos(\varphi + \varphi + \sigma + \sigma' - 2\nu) \right\}^2,$$

to the form,

$$M + M' \times e \sin \mu + M'' \times e' \sin \mu',$$

and then to multiply by it, retaining in the product only quantities of the first order relative to e and e'. Now in this there is no difficulty: but the complete development of the expression would be bulky, and would contain many arguments, the greater part of which are insignificant and useless, although some of them deserve attention in particular researches. Leaving astronomers to select from the general expression the arguments which may suit their purpose, we shall here close what we had to offer respecting the development of the disturbing function, without adding to the length of this paper by any application of what we have written.

May 30, 1833.

XXV. *On the Figures obtained by strewing Sand on Vibrating Surfaces, commonly called Acoustic Figures.* By Charles Wheatstone, *Esq.* *Communicated by* Michael Faraday, *Esq., D.C.L. F.R.S., &c. &c. &c.*

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§ 1.

HALF a century has nearly elapsed since the attention of philosophers was first called to the curious phenomena exhibited when sand is strewed on vibrating surfaces. Long before this time, Galileo had noticed that small pieces of bristle laid on the sounding-board of a musical instrument, were violently agitated on some parts of the surface, whilst on other parts they did not appear to move; and our own countryman Dr. Hooke, whose sagacity in anticipating many of the discoveries of later times has been so frequently remarked, had proposed to observe the vibrations of a bell by strewing flour upon it. But to Chladni is due the sole merit of having discovered the symmetrical figures exhibited on plates of regular forms when caused to sound. His first investigations on this subject, Entdeckungen über die Theorie des Klanges, were published in 1787; this work was followed by his Akustik in 1802, and his Neue Beyträge zur Akustik, 1817. A French translation, by himself, of his second work was published at Paris in 1809.

All the figures obtained by Chladni on square surfaces are delineated in pages 611, 613, 615; they are copied from the Neue Beyträge, which work contains his most mature experiments; but not having been translated either into French or English, it is but little known in this country. The following are the general results deduced by Chladni from his observations respecting these figures: his works may be referred to for the details omitted, and for those concerning the vibrations of plates in general.

In all the modes of vibration of a square or rectangular plate, the figures,

even if they consist of diagonal or tortuous lines, may all be referred to a certain number of nodal lines in the two directions parallel to the sides.

To establish a convenient notation for these figures, he represents the lines in the two directions by numbers separated by a vertical line. Thus, for example, 3|0 signifies the mode of vibration, in which there are three lines in one direction and none in the other; 5|2 denotes that in which there are five lines parallel to one side, and two to the other, &c.

The nodal lines, which may always be considered as having been originally straight, may curve themselves more or less; and in general the flexions of these lines, whether they adjoin each other or are separated by a straight line, mutually approach to or recede from each other. In some modes of vibration the nodal lines are never straight.

In some instances, the same mode of vibration may manifest itself in two essentially different ways, according as the flexions of the lines, or the greater number of them, are inward or outward; in the first case, the sound is usually graver than in the second. This difference is remarked in those figures where there is an entire number of flexions, as in 2|0, 3|1, 4|0, 5|3, 6|2, &c.; but never in those figures where there are $1\frac{1}{2}$, $2\frac{1}{2}$, &c., as in 3|0, 4|1, 5|0, 5|2, &c. To distinguish the first from the second figure, Chladni places a horizontal line above the numbers in the first case, and below them in the second case, thus, $\overline{4|2}$, $\underline{4|2}$.

When two or more figures having the same notation, occur in the Table, the others are to be considered as distortions of the first, occasioned by altering the fixed points, and the place at which the bow is applied.

If four plates of the same size, and upon which the same figure has been produced, be placed together so as to form a larger square, this compound figure may also be more or less accurately produced on a single larger plate. Several instances of this may be seen by reference to the Table of figures.

The following Table contains the relative sounds (expressed both by their musical names and the number of their vibrations,) of all the modes of vibration of a square plate, experimentally ascertained by Chladni. The horizontal series of numbers denotes the lines parallel to one of the sides, and the vertical series those parallel to the other.

TABLE.

1		G, 6								
2	D−, 9− E..F, 10+	B, 15	A¹..B¹ 27+, 28−							
3	G♯², 25	B′, 30 C³+, 32? 33?	F♯³, 45	C³+ 64, 65						
4	G♯²−, 49− G♯³, 50	B³, −, 55, 56−	C♯³, 70 D³, 72	F♯³ 90, 91	B³−, 110+, 112					
5	E³+, 81	F³, 84 F♯³, 90 91	G♯³, 98, 99, 100−	B⁴, 119 120 C⁴, 125 126 128−	D♯⁴, 150, 153	F♯⁴, 180				
6	B³, 120 121 C⁴−, 125 126	C⁴, 128	C♯⁴, 135 140 D⁴, 144	E⁴, 160 162	G⁴, 189 192 G♯⁴, 196 198 200−	B♭⁴, 224+ 231−	C⁵, 256 264			
7	F⁴, 169	F⁴ F♯⁴ 175? 180?	F♯⁴+ 180+? 189−?	G♯⁴+, 209 210 A⁴, 216 220	B⁴, 240 240	C♯⁵, 275 280 D⁵, 286 288	E⁵, 320 324 325	F♯⁵, 360 364		
8	B♭⁴, 224 225 B♭⁴+225? 231?		B⁴, 240 242 C⁵−245 250	C⁵+, 256+ 264−	D⁵, 286 288 D♯⁵, 294 299	F⁵, 336 338	G⁵, 377+ 384 G♯⁵, 390 392	A⁵, 432 435	B⁵, 480	
9	D⁵, 289		E⁵− 315	F⁵ 330 336 F⁵+, 343 345	F♯⁵, 360	G♯⁵−390 392	B♭⁵, 450	C⁶−, 495 C⁶ 510 512	C♯⁶+561	D♯⁶, 612
	0	1	2	3	4	5	6	7	8	9

The figures placed as exponents indicate the octaves in which the sounds occur; and the characters + and − denote that the sounds to the characters of which they are affixed are respectively sharper and flatter than the true intervals.

Having thus briefly stated the general results deduced by CHLADNI from his experimental researches, I shall proceed to class and analyse the phenomena; and I shall endeavour to show, that all the figures of vibrating surfaces are the resultants of very simple modes of vibration, oscillating isochronously, and superposed upon each other; the resultant figure varying with the component modes of vibration, the number of the superpositions, and the angles at which they are superposed. In this first part of the investigation I shall confine myself to the figures of square and other rectangular plates.

§ 2.

The most simple modes of vibration of a rectangular surface are those which exhibit quiescent lines parallel to one of its edges. EULER has theoretically established, that a rod or band, having both its ends unfixed, can vibrate with 2, 3, 4, 5, 6, &c. quiescent lines parallel to the ends, and that the corresponding numbers of vibration are very nearly as the squares of the arithmetical progression 3, 5, 9, 11, &c. These conclusions are fully confirmed by experiment. He has proved, moreover, that when the same mode of vibration of different plates is compared, the number of vibrations is inversely as the square of the length of the plate, but that increase of breadth occasions no difference in the sound; and that the distance from a free end to a quiescent line is rather less than half the distance between two quiescent lines.

Fig. 1. *a.* page 617, shows the number and situations of the quiescent lines in the first four modes of vibration of this series. Fig. 1. *b.* and *c.* are profiles of the preceding, and represent the curvature of each parallel fibre perpendicular to the quiescent lines at the two opposite limits of their vibration. The quantity of motion at each point is indicated by the corresponding ordinate of the curve, and its direction by its situation above or below the horizontal line. It will be convenient to distinguish these states of motion, in which every corresponding point is moving in direct opposition; and I shall therefore call the first, *b.* positive states of vibration, and the second, *c.* negative states of vibration. When there is an even number of quiescent points, the positive state of vibration may be considered as that in which the motion at the *central* part is above the plane of equilibrium, and the negative, that in which it is below it. If we suppose two similar surfaces with the same number of quiescent lines to

be superposed, and both to vibrate in concurrence, i. e. both either positively or negatively, they will mutually assist each other's effects; but if they vibrate in opposing directions, they will destroy each other's motions, and the entire surface will be at rest.

§ 3.

When the rectangular surface is equilateral, it is obvious that it may vibrate in two different rectangular directions, so as to give the same sound, and present the same arrangement of quiescent lines. Now this plate may be excited at various points where the motion of each mode of vibration is at its maximum, in the same direction, and of equal intensity: such being the case, there is no reason why one mode of vibration should be produced in preference to the other; and on calculating the effect of such coexistence, it will be found that the resultants of these combined modes of vibration, similar in everything but in their direction with regard to the sides of the plate, give rise to new quiescent lines which accurately correspond with figures described by Chladni; while the number of vibrations does not materially differ from that of the component modes of vibration.

The principal results of the superposition of two similar modes of vibration are these: 1st, The points where the quiescent lines of each figure intersect each other, remain quiescent points in the resultant figure; 2ndly, The quiescent lines of one figure are obliterated when superposed by the vibrating parts of the other; 3rdly, New quiescent points, which may be called points of compensation, are formed wherever the vibrations in opposite directions neutralize each other; and, lastly, At all other points the motion is as the sum of the concurring, or the difference of the opposing vibrations.

A primary figure, having an even number of quiescent lines, may be superposed two ways, and may consequently give rise to two distinct resultant figures: one, when the central vibrating parts concur; and the other, when they are in opposition; but if the number of the quiescent lines in the primary figure be uneven, there can be only one resultant figure.

The quiescent lines which thus result may be very easily ascertained. I will take as an example the first mode of vibration, having two parallel quiescent lines; this being superposed in two rectangular directions, and so that the states of vibration are opposing (page 617, fig. 2.), it is obvious that no lines of

compensation can exist in the four rectangular segments *a a a a*, as every point included within them is actuated by concurrent motions; but in all the other rectangles they must necessarily be formed, as every point within them is affected by the two opposing motions, and if the two modes be of equal intensity, the compensations must occur at every point equally distant from the two rectangular quiescent lines, each appertaining to a different mode of vibration. The resultant figure will thus be found to consist of two diagonal lines perpendicular to each other, and passing through the centre of the plate.

But if the two superpositions vibrate in concurrence, the rectangles *b b b b* will be free from compensating points; but these will occur in the other rectangles, and form the figure represented (fig. 3.), which also consists of diagonal lines.

In the same manner the resultant of any two similar modes of vibration with nodal lines, parallel to the sides, may be proved to consist of lines parallel to the diagonals.

§ 4.

It is not a necessary condition for the vibrations of a square plate that the primary nodal lines shall be parallel to a side; they may also be parallel to a diagonal, or to any line intermediate between a transverse and a diagonal line. In these cases the superpositions take place according to the following rule: That the axes of the superposed modes of vibration must make equal angles with a transversal line passing through the centre; for otherwise the modes of vibration would not be similar. By the axis of a primary mode of vibration, I mean a straight line passing through the centre of the plate and parallel to the quiescent lines. Considerations of the kind already employed will show that in all these instances the resultant figures consist of lines parallel to the edges of the plate, and that they are always the same in number as the nodal lines of a component mode of vibration, but differently distributed in the two directions, according as the angle of superposition varies.

The various primary modes of vibration, transverse, intermediate, and diagonal, and the angles which the quiescent lines of two similar figures make with each other when they are superposed, are represented in the first column of the general Table, page 619—633; in the second column of this Table are placed the figures resulting from their opposing superpositions, and in the third column those which arise from their concurring superpositions.

We obtain by experiment a limited number only of figures which can be considered the resultants of primary modes of vibration consisting of any given number of oblique lines; but it would seem, that as the various degrees of obliquity are infinite, so there should be an infinite number of resultant figures passing into each other by insensible gradations: by calculation this should be so, but there are causes of limitation which I shall proceed to explain.

It appears that no resultant figure is maintainable unless the greatest excursions of the external vibrating parts occur at the edges of the plate. In the concurring superpositions of eight oblique lines, this condition can only be fulfilled when the angles they make with each other are either 90°, or 143° 8′; in the first case the resultant figure consists of four lines in each transverse direction, in the second of six lines in one direction and two in the other. In the opposing superpositions of the same number of lines, the condition is fulfilled when the angles at which the lines are inclined are 118° 4′ and 163° 44′; the resultant figure of the former consists of five lines in one direction and three in the other, and that of the latter of seven in one direction and one in the other.

§ 5.

I have, in the preceding sections, described the various modes of binary superpositions which may take place on a square surface. But there are numerous cases in which four superpositions may coexist, and these I shall now proceed to take into consideration.

When the axis of a primary figure corresponds either with a diagonal or with a transverse line, passing through the centre of the plate, it is obvious that there can be only one other line of equal length, which can be considered as the axis of a similar and isochronous mode of vibration; in these cases it is evident, therefore, that there can only be two superpositions. But in every intermediate direction of an axis, there are three other lines of equal length which constitute axes of similar modes of vibration; and four superpositions can therefore take place whenever the axis of a component mode of vibration is neither a diagonal nor a transverse line.

It would be a tedious and laborious process to ascertain a resultant figure by combining its four component modes of vibration; but the same purpose will be effectually answered by combining them first in pairs, as explained in the

preceding section, and then combining two of these first resultants rectangularly together.

The following process affords great facility for ascertaining the second resultant figure, which arises from the superposition of two first resultants. *a*. and *b*. (fig. 4. page 617,) are the two component first resultants, the similar lines of one being placed rectangularly to those of the other; the vibrating parts are indicated by the letters P and N, according as the vibrations are positive or negative. At C the two figures are superposed, A being represented by the continuous and B by the dotted lines. The surface is now subdivided into a number of unequal rectangles, and by comparing the two component figures together, it is easy to see which of these rectangles are influenced by conspiring, and which by opposing motions; if the motions are found to conspire, the letters P or N must be placed in these rectangles according as the coexisting motions are positive or negative; if the motions are in opposition, a mark may be made to indicate that a quiescent line passes through this rectangle. Wherever a continuous line intersects a dotted line, a mark is to be made, to indicate that a quiescent point is formed; and as in every other part, the quiescent lines of one figure pass over vibrating parts of the other, the boundary lines of all the rectangles must be marked with the letters indicating the motions of the vibrating parts they superpose. The figure C being thus marked, the resultant figure is easily described by joining the fixed points by lines drawn through the rectangles shown to be actuated by opposing motions; carefully avoiding to encroach upon the rectangles of conspiring motion marked P or N.

That the diagonal line is perfectly straight may be proved in the following manner. It must first be premised that the rectangles included within the quiescent lines of each of the first resultant figures, have precisely the same quantity of motion in the same relative points with respect to the surrounding sides, and that the vibrating parts at the edges and corners of the plate must be considered respectively as exact halves and quarters of a complete vibrating part. This being understood, if two similar first resultants be laid alongside each other in the directions in which they are to be superposed, and if a diagonal line be similarly drawn through each of them, it will be obvious that every corresponding point of each line must possess the same intensity of motion. If the successive segments (equal in each figure,) through which the

lines simultaneously pass, be in opposite states of vibration, they will neutralize each other's effects, and a diagonal quiescent line will be formed; and if they be concurring, all the parts between the coincident or fixed points will be in motion. In the diagram (fig. 4. *c*.) one diagonal is in the first state and the other in the second.

If the number of lines in the component first resultant figures be uneven, they admit of only one mode of superposition. But first resultants having an even number of quiescent lines, admit of being superposed in two ways, according as they are vibrating in concurrence or in opposition.

It frequently occurs that entire quiescent lines superpose each other; thus, when in the component figure there is an uneven number of lines in each direction, the two rectangular central lines of each superposed figure must coalesce, and consequently they continue in both the resultant figures; examples of this are seen in the resultants of 3|1, 5|1, 5|3, 7|1, 7|3, 7|5, &c. Again, when the number of quiescent lines in one direction of the component figure is three times greater than that in the other, the number of coinciding fixed lines in each direction of the resultant figure is equal to the smallest number in the first resultant, as in 6|2, 9|3, 12|4, 15|5, &c. See the general Table, page 619—633.

The following general results are obtained from constructing the second resultant figures according to the rules above given.

In superposing first resultants consisting of an even number of lines: 1st, When the number of lines in each direction of the first resultants is even, and the modes of vibration are concurring, no line passes through the centre of the second resultant figure. When the modes of vibration are opposing, two rectangular diagonal lines of compensation occur. 2ndly, When the number of lines in each direction is uneven, and the modes of vibration are concurring, there are always two perpendicular transversal lines passing through the centre; and when the modes are opposing, there are, in addition to these fixed lines, the two diagonal lines of compensation.

When the first resultants consist of an uneven number of lines, in which case there is no distinction of concurring and opposing vibrations, one diagonal line only invariably occurs.

In no case is it necessary to calculate an entire figure. When the number of nodal lines in the primary mode of vibration is even, only one quarter of

the figure is required to be calculated, as it is obvious that every second resultant of this kind consists of four symmetrical, and as it were reflected, portions. But when the primary number of quiescent lines is uneven, it is necessary to calculate one half; the other half is symmetrical and inverted.

Some of the first resultants are never obtained by experiment. When the number of quiescent lines in the primary mode of vibration is uneven, either the first or the second resultant may be obtained at pleasure; thus in 3|2 if the impulses be made at a corner, where the motion of both superpositions is at its maximum, the second resultant must arise; but if they be made at the middle of a side, the first resultant only will appear, because the point of excitation is a quiescent point of the other. But in all cases where there is an *even* number of lines, it is impossible to obtain the first resultant, because each maximum of vibration equally belongs to both superpositions.

§ 6.

I have given in pages 619—633, a Table which shows every perfect resultant figure of a square surface when the number of quiescent lines in the primary modes of vibration does not exceed twelve. I have carefully calculated each figure by the rules laid down in the preceding sections, and have shown in the Table the successive processes of superposition. The first vertical row exhibits the two primary modes of vibration superposed at the required angles; one figure being represented by the continuous lines, and the other by the dotted lines. The second row contains the first resultants which arise from the opposing superpositions of the preceding; and the third row, those which result from their concurring superpositions. The fourth and fifth rows exhibit the perfect second resultants which are formed, the former by the opposing and the latter by the concurring superpositions of the first resultant which the plate has been already found competent to produce.

On comparing the calculated figures with those obtained experimentally by Chladni, the greater number are found exactly to agree; there are, however, some differences which it will be necessary to explain. In the first place, there is an obvious cause of error in delineating figures from experiment, from this circumstance,—that the sand accumulates in the spaces where two convex curves are near and opposite to each other, the motion being there very small, so that it is difficult to ascertain whether the curves join, or not. Secondly,

Inequalities in the plate will sometimes occasion lines which ought to intersect each other, so as to appear separated curves. On comparing together the figures CHLADNI has marked as $6\underline{|}4$, $\overline{6|}4$, $7|2$, $7|4$, $8|3$ *c.* &c. with those of the calculated Table, they will be found to differ only in these respects.

Another cause of difference is this: When the lines of one component figure very nearly coincide with those of the other, but without actually doing so, the resultant figure may be such as would arise from their actual superposition, instead of that which accurate calculation would give. In CHLADNI's Table there are two instances of this alteration, $7|2\,a$. and $8|3\,a$.

A few of the figures delineated by CHLADNI are irregular resultants formed by the superpositions of dissimilar modes of vibration. These irregular resultants can be formed only when the dissimilar component modes of vibration give the same sound, and have a maximum point of vibration in common, at which they can be simultaneously excited. The figure marked by CHLADNI 6|1, I find to be an irregular resultant formed by the combination of 6|1 with 3|5, which both give the same sound C^4. The irregular figure marked in his Table $5|1\,a$. is a compound of 5|1 and 2|5.

The calculated figures 6|1, 7|1, 8|1, 9|1, 10|1, 10|2, and 11|1, are not to be found in CHLADNI's Table. The near approach of the inclined lines of their primary component figures to parallelism is the cause of the great difficulty in obtaining these figures by experiment.

The figures marked by CHLADNI 10|3, 9|4, 8|5, 7|6, 10|4, 9|5, 8|6, and 9|7, exceed the limits within which I have calculated the Table, and are therefore not to be found in it.

§ 7. *Imperfect resultant Figures.*

I have hitherto considered those resultant figures only which arise from the superpositions of similar modes of vibration, each exactly equal in intensity; these I shall in future call *perfect* resultant figures. But when the vibrations of the superposed modes are unequal in intensity, then a figure intermediate between the perfect resultant and one of its components is formed; these intermediate figures I shall call *imperfect* resultants. They are experimentally obtained by varying in a slight degree the places at which the plate is held or touched, from those necessary to determine the corresponding perfect resultant figure; the place at which the bow is applied remaining in both cases the same.

Fig. 6. *a. b. c. d. e.* in CHLADNI's Table, page 611, represents the successive

transformations of figure which take place when each component mode of vibration presents three transversal lines: *a.* and *e.* are the two components; *c.* the perfect resultant; *b.* an imperfect resultant, in which the excursions of *a.* are the greatest: and *d.* an imperfect resultant, in which *e.* has the greatest energy.

Fig. 11. *a. b.* page 611, exhibits the transitions of the opposing superposition of two primary figures, each presenting four transversal lines; and fig. 12. *a.* and *b.* the changes of the concurring superposition of the same.

These are the principal types of the transformation of primary figures into first resultants. In each of these series of transitions there are certain points which are invariable during every change: these are, the quiescent points formed by the nodal lines of one figure intersecting those of the other, and the centres of vibration where the maxima of positive or negative vibration agree in each component mode of vibration. The points of compensation are changeable.

Figs. 29. *a.* and 30. *a.* page 613, represent imperfect second resultants, formed by two superpositions of the first resultant figure 6|2. Fig. 29. *a.* arises from concurring, and fig. 30. *a.* from opposing superpositions. The straight lines in these imperfect figures arise from the coincidence of entire quiescent lines in each component figure, and, consequently, they remain unaltered whatever may be the relative intensities of the superposed modes of vibration. But the curved lines, which are formed of compensating points, change with the varying intensities.

§ 8. *Figures of irregular Plates.*

If the sides of the square be nearly, but not exactly, equal, the superpositions of two similar modes of vibration with transversal lines still take place; but instead of exhibiting perfect resultants, figures resembling transitional figures appear. Thus in the binary superposition (page 611, fig. 1.) of the figure with two transversal lines, if the sides be unequal, the crossed lines separate at their point of intersection and are converted into two curves, the summits of which recede from each other as the difference in the lengths of the sides becomes greater.

Also, if the diagonals of the square be unequal, the resultant figure (page 611, fig. 2.) arising from two superposed modes of vibration with diagonal axes, will be modified in a similar manner.

Corresponding modifications are occasioned, through accidental differences of elasticity, &c. in the directions of the axes of the superposed modes of vibration, even when the dimensions of the plate are apparently equal.

If a plate of glass be covered on one of its sides with leaf-gold, or if a plate of ground glass be substituted for an ordinary glass plate with smooth surfaces, the figures may be obtained distinctly delineated by lines consisting of a single row of grains of sand. Experiments made in this manner, upon square plates carefully prepared, induced Professor STREHLKE to conclude, after many minute measurements of these lines, that all acoustic figures are formed of hyperbolic curves, and that the quiescent lines never intersect each other. But however correct these experiments may have been, the conclusions drawn from them are unwarranted; were it possible to obtain plates of a perfectly homogeneous substance, and of accurately equal dimensions, there can be no doubt that the lines, however finely defined, would actually intersect each other.

§ 9.

I have already, § 1., given CHLADNI's Table of the comparative sounds, and numbers of vibrations of the figures of square surfaces obtained from experiment. In the following Table these results are arranged so as to correspond with the views taken in this paper. The numbers in the first vertical row indicate the number of parallel quiescent lines in the primary figure. In the horizontal rows the angles at which the lines of the primary modes of vibration intersect each other are shown; and the figures between brackets give the notation of the first resultant produced by their superposition; below these its number of vibrations, and the character representing its musical sound, are given; when there are two of these lower lines separated by a horizontal dash, the one above indicates the sound of the opposing superposition, and that below it the concurring superposition.

Thus it appears, that every figure of a square surface which experiment can give, may be reduced to a primary figure with parallel lines, giving the same sound: if, therefore, the analytical investigation be confined to these, many of the difficulties will disappear. EULER has investigated the subject when lines parallel to a side only are concerned; it remains to extend the inquiry to modes of vibration the nodal lines of which are perpendicular to any line passing through the centre of the surface. An analytical expression for all the sounds of a square plate may probably be obtained, which shall be a function of the number of quiescent lines, and the length of the axis of the mode of vibration.

TABLE.

2	90° (1|1) G, 6	180° (2|0) D−, 9 E..F, 10+					
3	126° 52′ (2|1) B, 15	180° (3|0) G♯¹, 25					
4	90° (2|2) A¹..B¹, 27+, 28−	143° 8′, (3|1) B¹, 30 C²+, 32.?.33.?	180° (4,0) G♯²−, 49− G♯², 50				
5	112° 38′, (3|2) F♯², 45	151° 56′, (4|1) B²−, 55..56−	180°, (5|0) E²+, 81				
6	90°, (3|3) C³+, 64.65	126° 52′, (4,2) C♯³, 70 D³, 72	157° 22′ (5|1) F³, 84 F♯³, 90.91	180° (6|0) B³, 120..121 C⁴−, 125..126			
7	106° 16′ (4|3) F♯³, 90..91	136° 22′ (5|2) G♯³, 98.99.100−,	161° 4′ (6|1) C⁴, 128	180° (7|0) F⁴, 169			
8	90° (4|4) B♭³−, 110+.112	118° 4′, (5|3) B³.119.120 C⁴, 125.126.128−	143° 8′ (6|2) C♯⁴ 135.140 D⁴.144	163° 44′ (7|1) F⁴..F♯⁴ 175.? 180.?	180° (8|0) B♭⁴ 224.225 B⁴+225+231.?		
9	102° 40′ (5|4) D♯⁴ 150.153	126° 52′ (6|3) E⁴ 160.162	148° 6′ (7|2) F♯⁴+.180+.?189−	165° 44′ (8|1)	180° (9|0) D⁵ 289		
10	90° (5|5) F♯⁴, 180	112° 38′ (6|4) G⁴ 189..192 G♯⁴ 196.198.200−	133° 26′ (7|3) G♯⁴+ 209.210 A⁴, 216.220	151° 56′ (8|2) B⁴ 240.242 C⁵− 245.250	167° 18′ (9|1) unascertained.	180° (10|0)	
11	100° 24′ (6|5) B♭⁴, 224+, 231−	120° 30′ (7|4) B⁴ 240.242	138° 52′ (8|3) C⁵+, 256+.264−	154° 56′ (9|2) E⁵− 315	168° 34′ (10|1)	180° (11|0)	
12	90° (6|6) C⁵ 256+.264−	108° 56′ (7|5) C♯⁵, 275.280 D⁵, 286.288	126° 52′ (8|4) D⁵, 286.288 D♯⁵ 294.299	143° 8′ (9|3) F⁵, 330.336 F⁵+ 343, 345	157° 22′ (10|2)	169° 36′ (11|1)	180° (12|0)

§ 10.

Immediately after the publication of CHLADNI's experiments on square plates, JAMES BERNOUILLI attempted to demonstrate them analytically; but his investigation was entirely unsuccessful; his conclusions were founded on erroneous data, and the results he obtained were at variance with experiment. His assumptions were these: that the primary figures consisted of 2, 3, 4, 5, 6, 7, &c. lines parallel to the side only, these being the modes of vibration of a lamina as investigated by EULER; that any two similar or dissimilar modes of vibration might superpose each other rectangularly, the nodal lines of the two components appearing together in the resultant mode of vibration; and that the sound of the resultant differed from that of either of the two components, being much higher. The figures given by experiment he considered accidental distortions of these compound figures. This theory gave no account of those figures in which a single line in one direction coexists with any number in the other, as there is no primary figure consisting of one nodal line only; and BERNOUILLI acknowledged his theory to be imperfect in this respect.

The failure of BERNOUILLI led CHLADNI inconsiderately to state, that "the supposition of regarding such a rigid membraniform body as a network formed by curved lines in one direction applied upon curved lines in another direction, is not conformable to nature, and will never give, either results agreeing with experiment, or an appearance of explanation of some of the most simple vibrations." That this assertion is erroneous, the considerations in the present paper have, I conceive, fully proved. The error of BERNOUILLI did not consist in assuming that the observed acoustic figures were formed by superposing simple modes of vibration on each other, for this has been shown to be true; but in his assumptions of the manner in which these superpositions were made, and the effects which resulted from such hypothetical superpositions.

The various mathematicians who have more recently undertaken to investigate the laws of vibrating surfaces, as POISSON, CAUCHY, Mademoiselle GERMAIN, &c., do not appear to have taken into consideration anything resembling the theory of superposition.

Dr. YOUNG seems to have had a correct notion of the origin of the acoustic figures; for in his Lectures, when slightly noticing CHLADNI's experiments, he remarks, "The vibrations of plates differ from those of rods in the same man-

ner as the vibrations of membranes differ from those of chords, the vibrations which cause the plate to bend in different directions being combined with each other, and sometimes occasioning singular modifications."

The brothers Weber, in their excellent work the Wellenlehre, published in 1825, have advanced a step nearer the truth than any of their predecessors. They have shown, that in a square vessel containing water or mercury, two series of stationary waves, one parallel to each side, may be made to intersect each other; and that the compound wave formed by their interferences assumes the form shown in § 3. to be the resultant of two superpositions of parallel transverse lines. Their observations are confined to those modes of undulation, analogous to the first resultants of primary modes of vibration with lines parallel to a side. Though I had advanced considerably in the present inquiry before I saw this work, yet I should be wanting in justice to these philosophers did I not here state that theirs is the merit of having shown, in the most simple case, the way in which the superpositions of modes of vibration or undulation actually do take place.

§ 11. *Plates of Wood.*

From the rules already laid down, it is obvious that the series of figures presented by a square plate of any homogeneous material ought not to be obtained on a square plate of wood, in which substance the elasticity is not the same in all directions. If a square plate of wood be prepared with its fibres parallel to one of the sides of the square, the axes of greatest and least elasticity will be disposed rectangularly, and parallel to the adjacent sides; in this case the same primary mode of vibration in the two directions will not give the same sound, although the dimensions of the vibrating parts are the same in both; consequently they cannot coexist, and the resultant figures with diagonal lines will be wanting on such a plate. But if the axes of the two component modes of vibration be equally inclined to either of the axes of elasticity, these modes of vibration will be necessarily similar and isochronous, and therefore capable of superposition; on a square plate of wood, consequently, all those first resultants which consist of any number of lines parallel to the sides intersecting each other rectangularly, may be obtained; and the same figure will be accompanied by different sounds, according as the axes

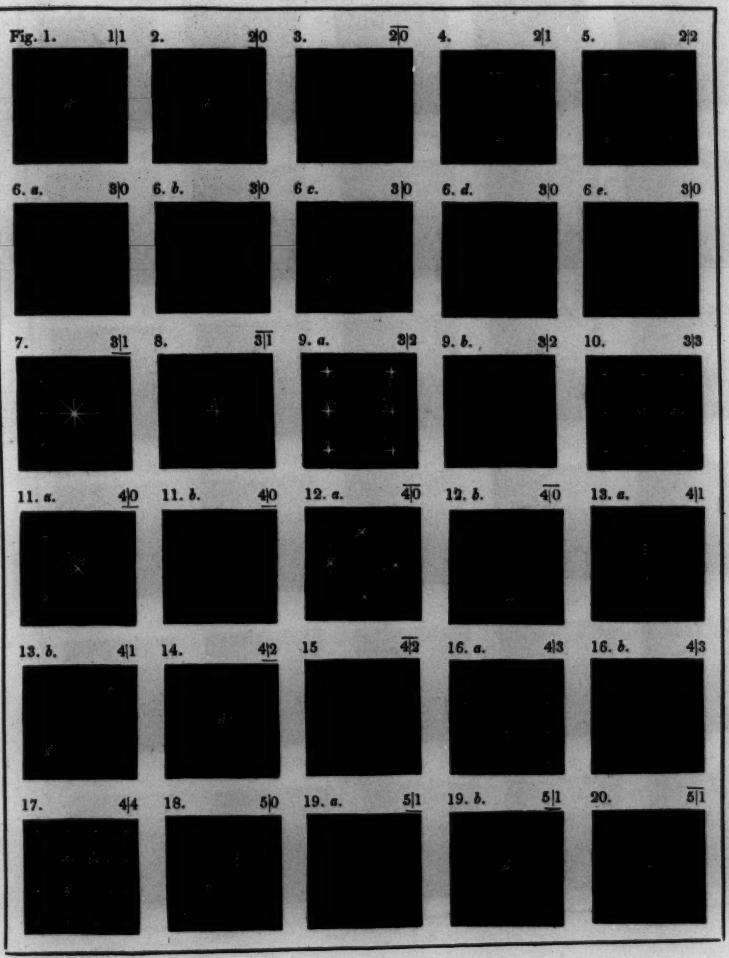
of the modes of vibration are inclined to the axes of least or greatest elasticity. It is easy to foresee that none of the second resultants, which consist of four isochronous superpositions, can be obtained on such a plate.

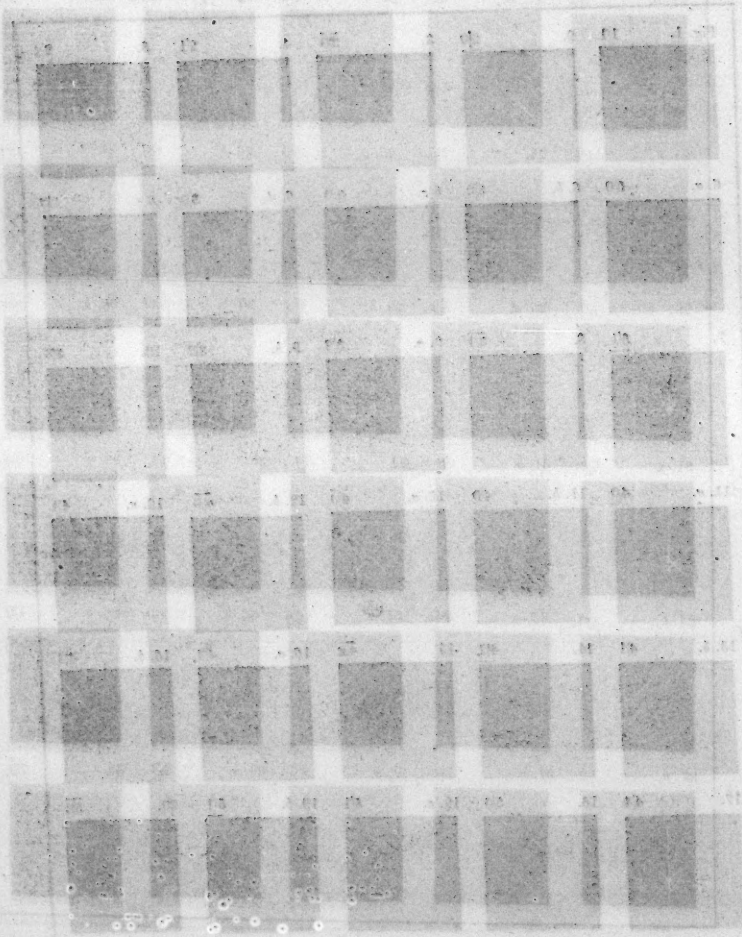
But if the wooden plate, instead of being square, be a rectangle, the sides of which are inversely as the squares of their resistance to flexion, the two modes of vibration parallel to the sides, though differing in length, will be isochronous; and their coexistence will give rise to a resultant figure with lines parallel to the diagonal. Thus on a rectangular plate of straight-fibred deal wood, in which the proportion of the sides were as 28 to 59, I obtained the two crossing diagonal lines, corresponding to the second figure of a homogeneous square plate of glass or metal.

Savart has made a series of numerous and accurate experiments on the changes which take place in the sound, and also in the form and position of the figure of the first mode of vibration on circular plates of wood of similar dimensions, cut in different directions with respect to the three principal axes of elasticity. All the results he has obtained are in perfect accordance with the rules stated in this paper, and might have been predicted by them. He has extended his investigations to circular slices of crystals, cut in various directions with respect to their axes, and has obtained in this way much valuable information. These researches of Savart point out a new direction to our inquiries respecting the structure of bodies; and the utility of his experiments will be greatly enhanced by the knowledge we now possess of the causes on which these phenomena depend. I shall shortly return to this subject.

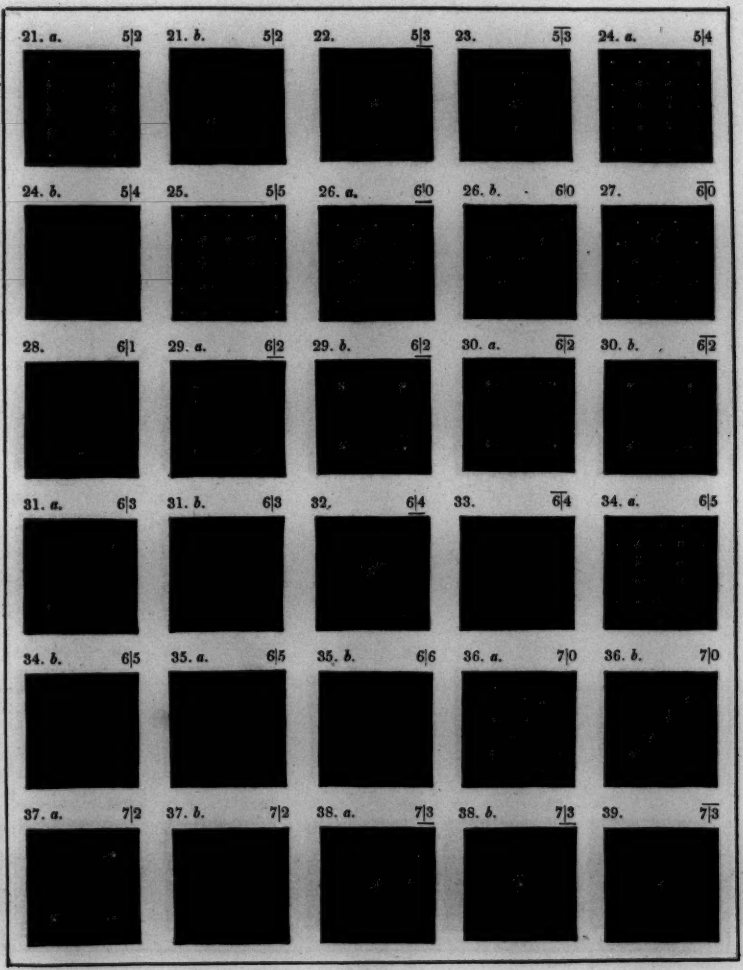
Chladni's Table

Of the figures of square surfaces, obtained by experiment.

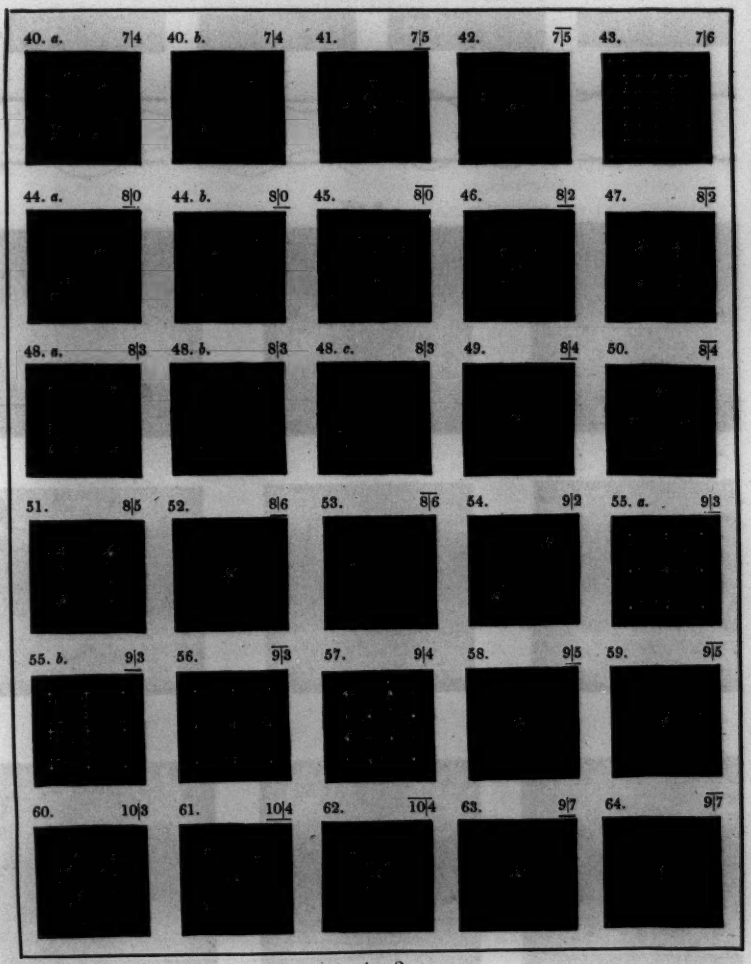




(Continuation of CHLADNI'S TABLE.)



(Continuation of CHLADNI'S TABLE.)



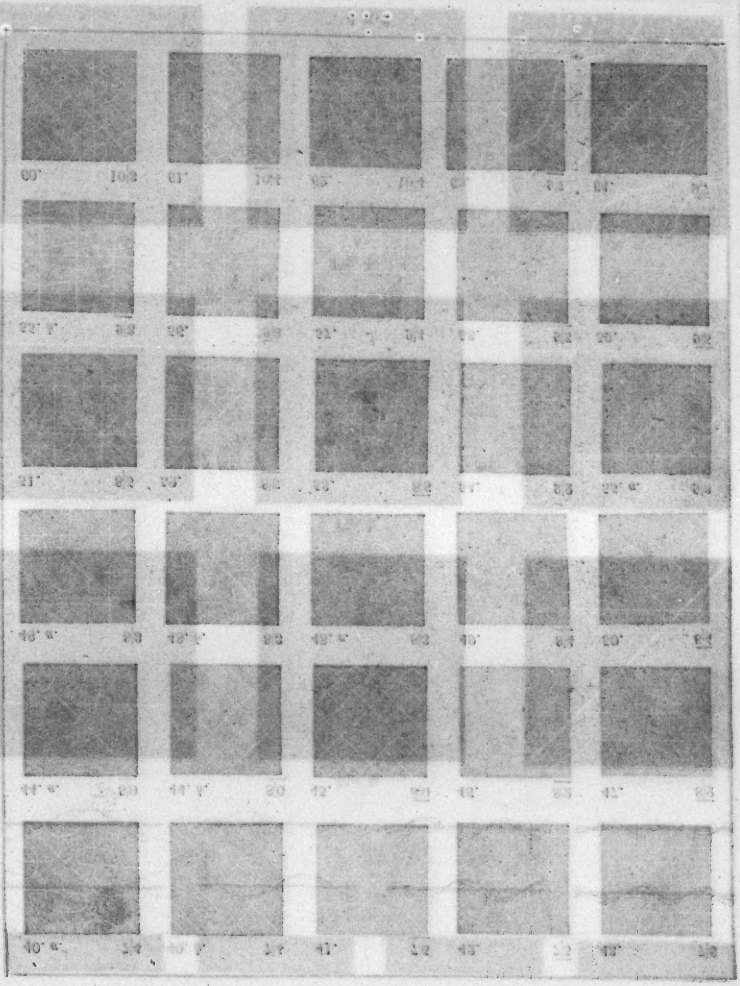


Fig. 1.

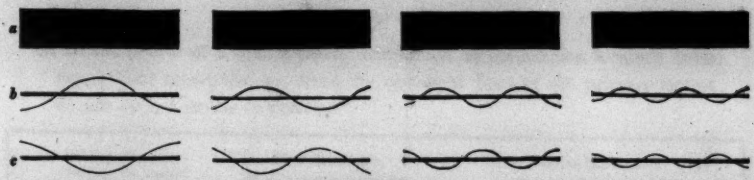


Fig. 2.

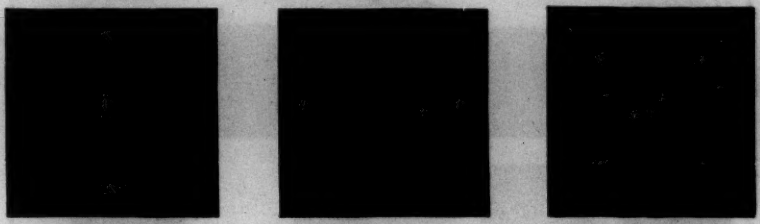


Fig. 3.

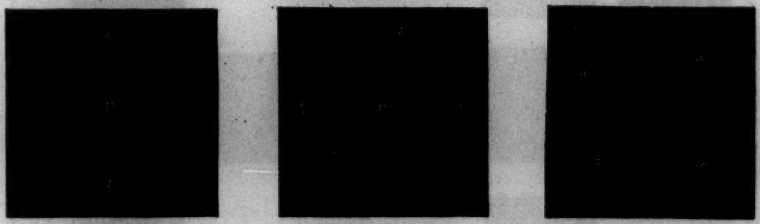
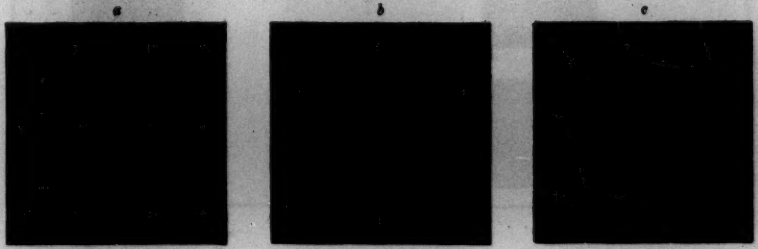
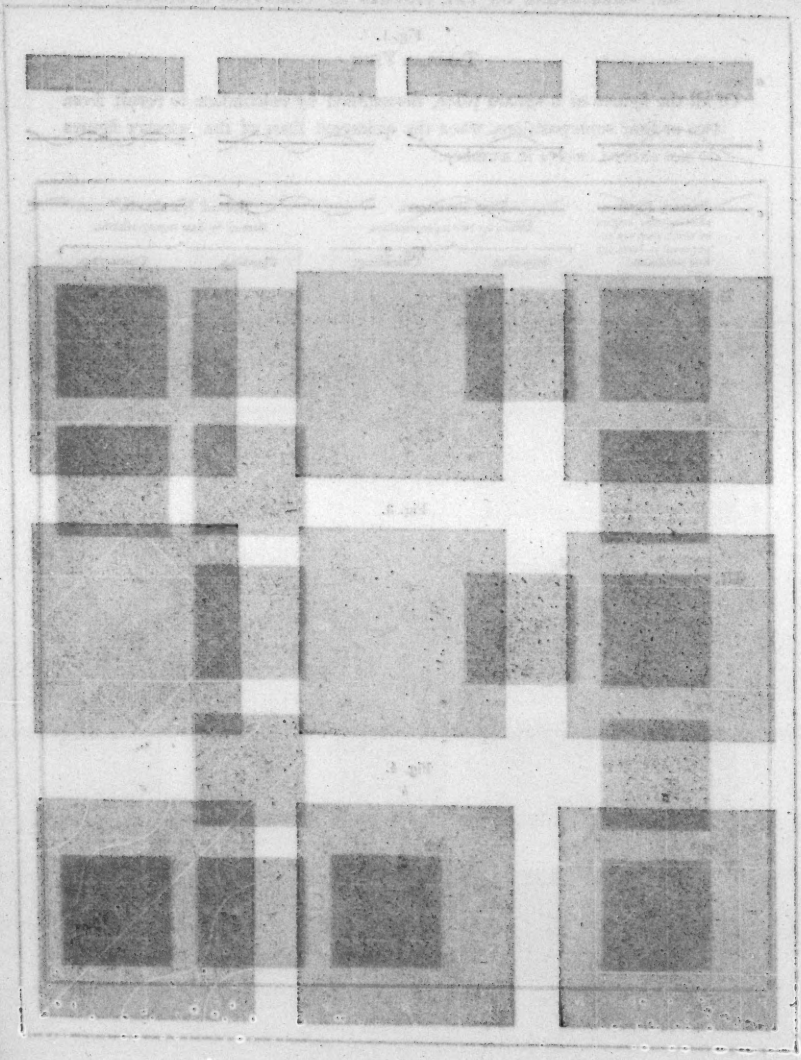


Fig. 4.





Tabular View

Of all the figures of a square plate, determined by calculation to result from two or four superpositions, when the quiescent lines of the primary figures do not exceed twelve in number.

Primary Figures, showing the angles at which they are superposed to form the first resultants.	First Resultants, formed by two superpositions.		Second Resultants, formed by four superpositions.	
	Opposing.	Concurring.	Opposing.	Concurring.
II. 90°	1|1			
180°				
III. 126° 52′	1|2			
180°				
IV. 90°		2|2		

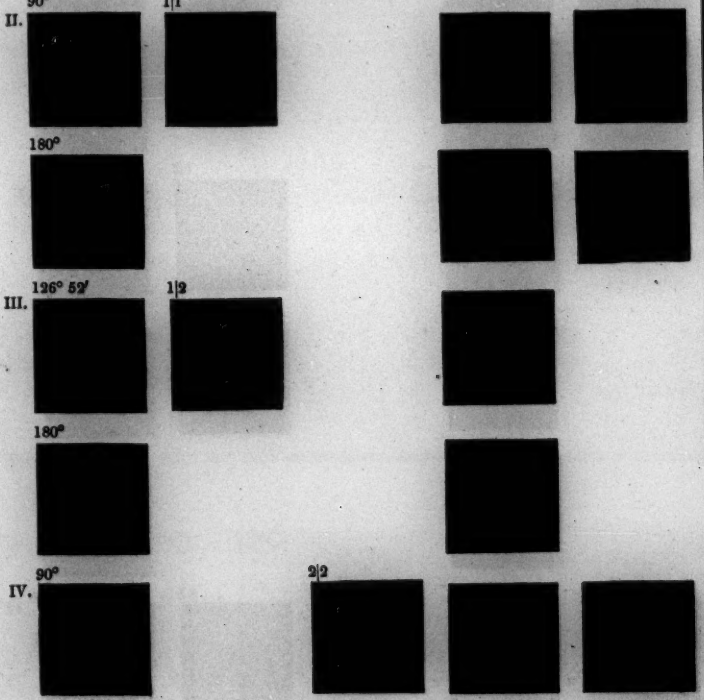


TABLE of Calculated Figures.—(Continued.)

	Primary Figures, showing the angles at which they are superposed to form the first resultants.	First Resultants, formed by two superpositions.		Second Resultants, formed by four superpositions.	
		Opposing.	Concurring.	Opposing.	Concurring.
	143° 8′	1|3			
	180°				
V.	112° 38′	2|3			
	151° 56′	1|1			
	180°				
VI.	90°	3|3			

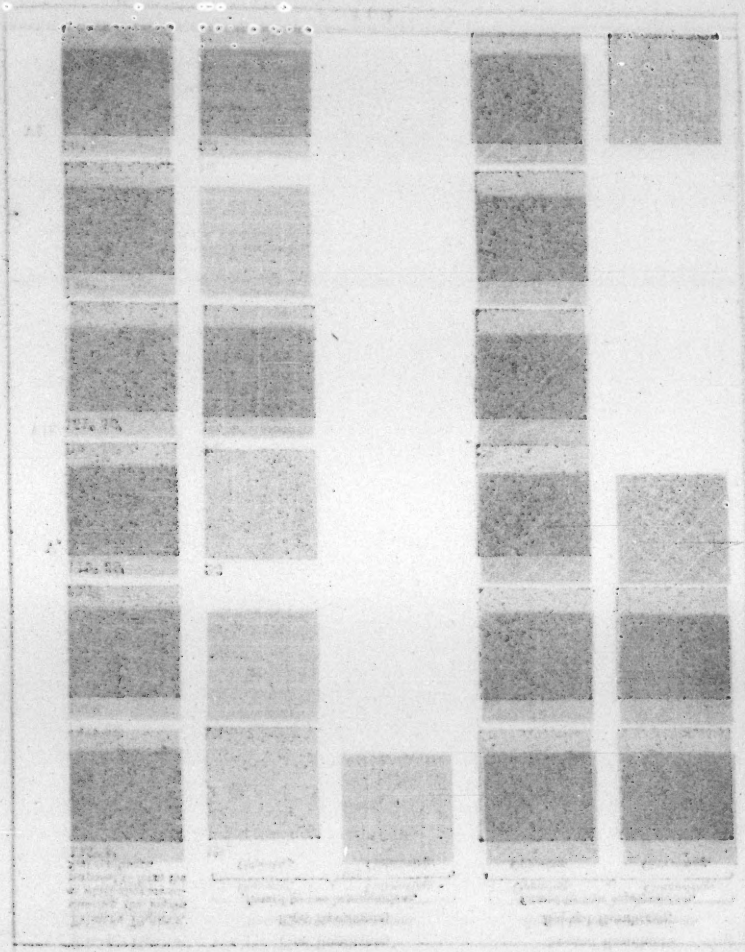


TABLE of Calculated Figures.—(Continued.)

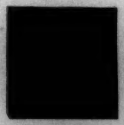
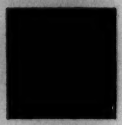
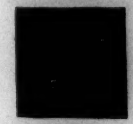
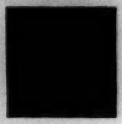
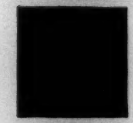
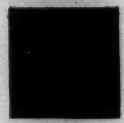
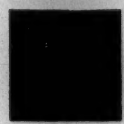
	Primary Figures, showing the angles at which they are superposed to form the first resultants.	First Resultants, formed by two superpositions.		Second Resultants, formed by four superpositions.	
		Opposing.	Concurring.	Opposing.	Concurring.
	126° 52′		2|4		
	157° 22′	1|5			
	180°				
VII.	106° 16′	3|4			
	136° 22′	2|5			
	161° 4′	1|6			

Table of Colonial Figures.—(Continued.)

TABLE of Calculated Figures.—(Continued.)

	Primary Figures, showing the angles at which they are superposed to form the first resultants.	First Resultants, formed by two superpositions.		Second Resultants, formed by four superpositions.	
		Opposing.	Concurring.	Opposing.	Concurring.
VIII.	180°				
	90°		4|4		
	118° 4′	3|5			
	143° 8′		2|6		
	163° 44′	1|7			
	180°				

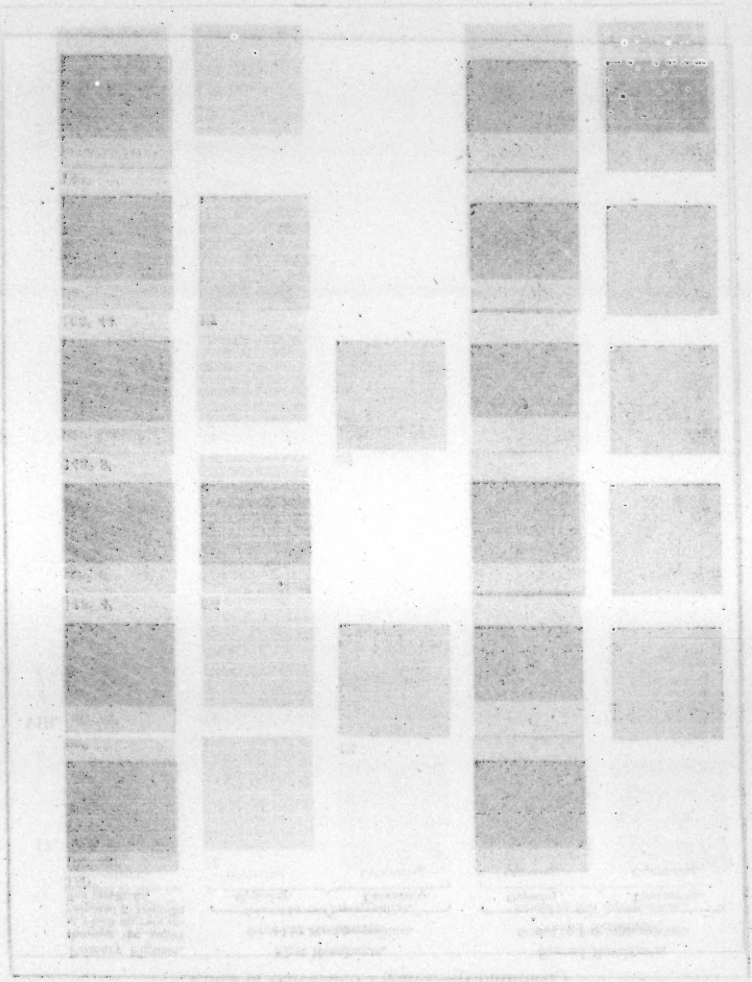
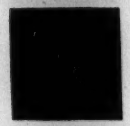
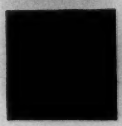


TABLE of Calculated Figures.—(Continued.)

	Primary Figures, showing the angles at which they are superposed to form the first resultants.	First Resultants, formed by two superpositions.		Second Resultants, formed by four superpositions.	
		Opposing.	Concurring.	Opposing.	Concurring.
IX.	102° 40′	4|5			
	126° 52′	3|6			
	148° 6′	2|7			
	165° 44′	1|8			
	180°				
X.	90°	5|5			

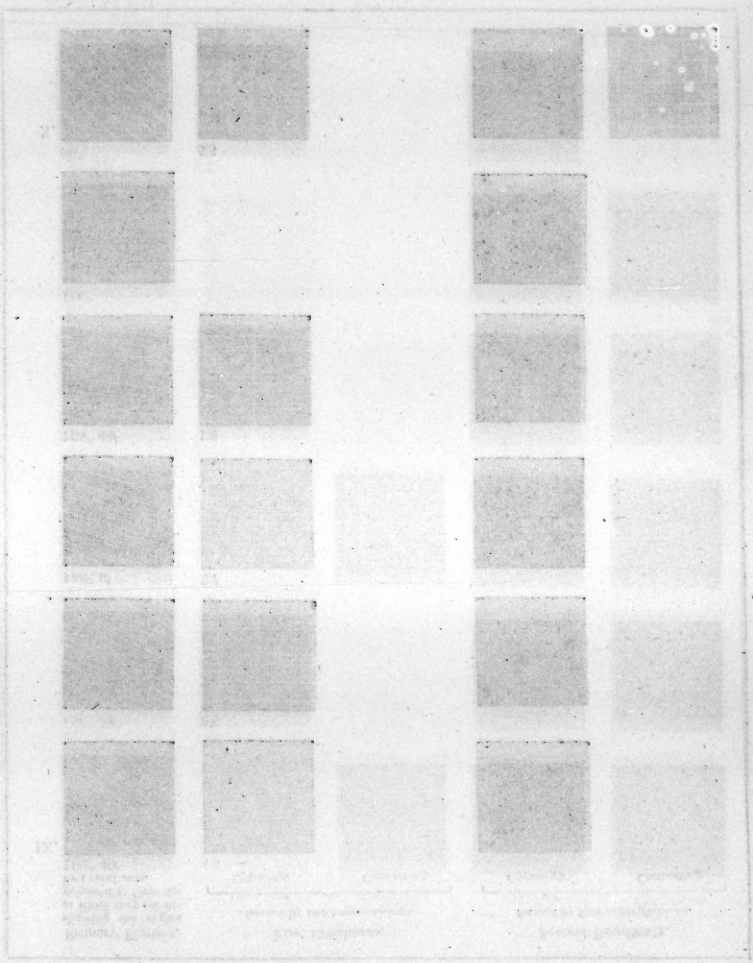


TABLE of Calculated Figures.—(Continued.)

Primary Figures, showing the angles at which they are superposed to form the first resultants.	First Resultants, formed by two superpositions.		Second Resultants, formed by four superpositions.	
	Opposing.	Concurring.	Opposing.	Concurring.
112° 38′		4|6		
133° 26′	3|7			
151° 56′		2|8		
167° 18′	1|9			
180°				
100° 24′	5|6			

XI.

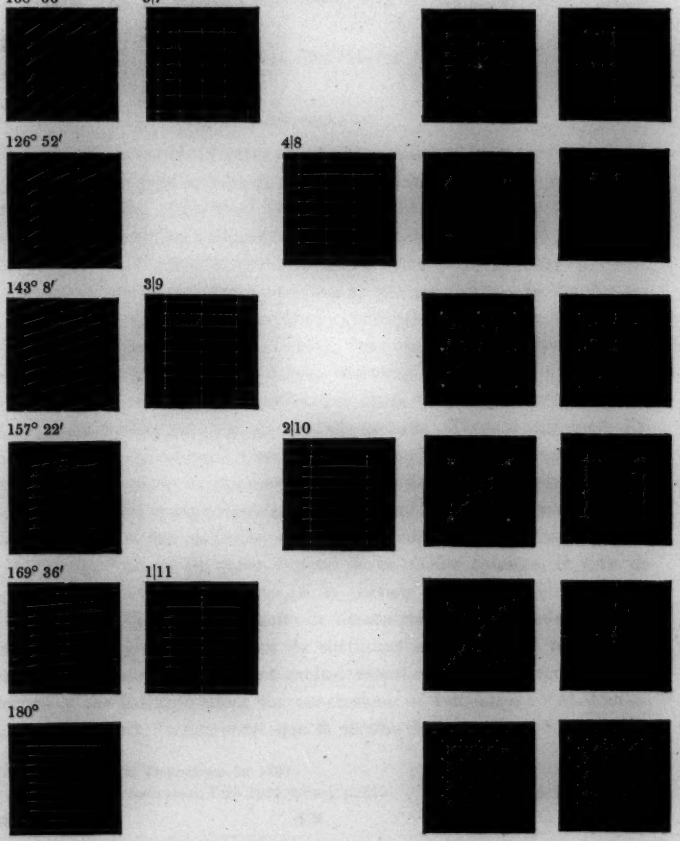
Table of Calculated Figures.—(Continued.)

	Primary Figures, showing the angles at which they are superposed to form the first resultant.	First Resultants, formed by two superpositions.		Second Resultants, formed by four superpositions.	
		Opposing.	Concurring.	Opposing.	Concurring.
	120° 30′	4|7			
	138° 52′	3|8			
	154° 56′	2|9			
	168° 34′	1|10			
	180°				
XII.	90°		6|6		

Table of Calculated Figures.—(Continued)

TABLE of Calculated Figures.—(Continued.)

Primary Figures, showing the angles at which they are superposed to form the first resultants.	First Resultants, formed by two superpositions.		Second Resultants, formed by four superpositions.	
	Opposing.	Concurring.	Opposing.	Concurring.
108° 56′	5|7			
126° 52′		4|8		
143° 8′	3|9			
157° 22′		2|10		
169° 36′	1|11			
180°				



XXVI. *On the Reflex Function of the Medulla Oblongata and Medulla Spinalis.* *By* MARSHALL HALL, *M.D., F.R.S. L. & E., &c. &c.*

Received June 11,—Read June 20, 1833.

1. *Introduction.*

THE higher departments of every science are doubtless its general principles and its laws. These have a claim to our consideration beyond that of insulated facts or mere details. Impressed with this truth, I have hitherto devoted my attention chiefly to the laws and principles of physiology. In a former memoir*, I gave the outline of one of the most general of the laws of this science,—that of the inverse ratio of the respiration and of the irritability. In the present memoir, I propose to give an account of a principle of action in the animal economy, which has not hitherto, I think, been distinguished with sufficient precision from the other vital and animal functions.

The principle to which I have adverted is connected, in a peculiar manner, with the medulla oblongata and the medulla spinalis. There is still much discrepancy of opinion amongst physiologists, in regard to the properties and functions of these parts of the nervous system. LEGALLOIS concluded, from his interesting series of experiments, that the spinal marrow, as a whole, and in distinct portions, is the exclusive source of sensation and voluntary motion. He observes†, "La vie du tronc dépend de la moëlle épinière, et celle de chaque partie dépend spécialement de la portion de cette moëlle dont elle reçoit ses nerfs. De plus, il est facile de démontrer que cette prérogative de la moëlle épinière, d'être la source du sentiment et de tous les mouvemens volontaires du tronc, lui appartient exclusivement à tout autre organe." The Reporters of the Institute adopt the conclusions of LEGALLOIS: "M. LEGALLOIS," they observe‡, "a démontré que la section de la moëlle épinière sur les

* Philosophical Transactions for 1832.

† Œuvres de LEGALLOIS, Paris 1824, tome i. p. 62. ‡ Ibid. p. 251.

premières ou sur les dernières vertèbres cervicales, n'arrête que les mouvemens inspiratoires, et qu'elle laisse subsister dans tout le corps le sentiment et les mouvemens volontaires. Cette distinction est capitale: personne ne l'avait faite avant lui*." M. CRUVEILHIER, on the other hand, denounces this view of the functions of the spinal marrow as one of the errors of modern physiology. He observes†, "L'indépendence des diverses parties de la moëlle les unes des autres, l'indépendence de la moëlle du cerveau, assez généralement admise dans ces derniers temps, me parait une grave erreur physiologique fondée sur d'ingénieuses expériences. L'opinion des anciens, qui regardaient la moëlle comme un gros cordon nerveux destiné à répondre lui seul à tous les nerfs de l'économie, pour transmettre en définitive au cerveau les impressions, ou pour en recevoir les impulsions volontaires ou organiques, cette opinion est bien plus en harmonie avec les faits, avec la grande loi anatomique de la continuité du système nerveux."

It will not be difficult to prove that the conclusions of LEGALLOIS and the Reporters of the Institute, are not legitimate deductions from the facts before them. But M. CRUVEILHIER altogether overlooks these facts, which are amongst the most interesting in physiology, and adopts an opinion which, however true, is far too exclusive.

On the more recent occasion of a report upon the admirable work of M. FLOURENS, the Perpetual Secretary of the Institute states his opinion on this point in a manner far more problematical. "L'auteur," he observes, "conclut que la sensation et la contraction n'appartiennent plus à la moëlle épinière qu'aux nerfs; et cette conclusion est certaine pour les animaux entiers. Ce serait une grande question de savoir si elle l'est également pour les animaux qui ont perdu leur encéphale, et qui, dans certaines classes, paraissent loin de perdre sur-le-champ leurs fonctions animales‡."

* More recently, M. MAGENDIE, M. LALLEMAND, and M. OLLIVIER have repeated the same opinion: Anatomie des Systèmes Nerveux, par A. DESMOULINS, Paris 1825, p. 561, &c.; Observations Pathologiques propres à éclairer la Physiologie, ed. 2, Paris 1825, pp. 88, 96, &c.; Traité de la Moëlle Épinière, ed. 2, Paris 1827, p. 17, &c. The subject is unnoticed by M. SERRES: Anatomie Comparée du Cerveau, Paris 1824. The physiologists of our own country have adopted the same views: Philip on the Vital Functions, ed. 3, p. 120; MAYO's admirable Outlines of Human Physiology, ed. 3, p. 227–231, &c.

† Anatomie Pathologique, Fasc. III.

‡ Du Système Nerveux, par P. FLOURENS, Paris 1824, p. 70.

It was a singular mistake to imagine that the same conclusion could be just in reference to the entire animal, which was incorrect in reference to the animal deprived of its encephalon. The facts are these: in the entire animal, sensation and voluntary motion, functions of the cerebrum, combine with the functions of the medulla oblongata and medulla spinalis, and may therefore render it difficult or impossible to determine those which are peculiar to each; if, in an animal deprived of the brain, the spinal marrow, or the nerves supplying the muscles, be stimulated, those muscles, whether voluntary or respiratory, are equally thrown into contraction, and, it may be added, equally in the complete and in the mutilated animal; and, in the case of the nerves, equally in limbs connected with and detached from the spinal marrow.

The operation of all these various causes of muscular contraction may be designated *centric*, as taking place *at*, or at least in a direction *from*, central parts of the nervous system. But there is another function the phenomena of which are of a totally different order and obey totally different laws, being excited by causes in a situation which is *eccentric* in the nervous system, that is, distant from the nervous centres. This mode of action has not, I think, been hitherto distinctly understood by physiologists. It is involved in the question which Baron Cuvier considers as so full of interest, and is that treated of in the following pages.

Many of the phenomena of this principle of action, as they occur in the limbs, have certainly been observed. But, in the first place, this function is by no means confined to the limbs: for, whilst it imparts to each muscle its appropriate tone, and to each system of muscles its appropriate equilibrium or balance, it performs the still more important office of presiding over the orifices and terminations of each of the internal canals in the animal economy, giving to them their due form and action; and, in the second place, in the instances in which the phenomena of this function have been noticed, they have been confounded, as I have stated, with those of sensation and volition; or, if they have been distinguished from these, they have been too indefinitely denominated instinctive, or automatic. I have been compelled, therefore, to adopt some new designation for them, and I shall now give the reasons for my choice of that which is given in the title of this paper.

This property is characterized by being *excited* in its action, and *reflex* in its

course: in every instance in which it is exerted, an impression made upon the extremities of certain nerves is conveyed to the medulla oblongata or the medulla spinalis, and is reflected along other nerves to parts adjacent to, or remote from, that which has received the impression.

It is by this reflex character that the function to which I have alluded is to be distinguished from every other. There are, in the animal economy, four modes of muscular action, of muscular contraction. The *first* is that designated *voluntary*: volition, originating in the cerebrum, and spontaneous in its acts, extends its influence along the spinal marrow and the motor nerves, in a *direct line*, to the voluntary muscles. The *second* is that of the *respiration*: like volition, the motive influence in respiration passes in a *direct line* from one point of the nervous system to certain muscles; but as voluntary motion seems to originate in the cerebrum, so the respiratory motions originate in the medulla oblongata: like the voluntary motions, the motions of respiration are spontaneous; they continue, at least, after the eighth pair of nerves has been divided. The *third* kind of muscular action in the animal economy is that termed *involuntary*: it depends upon the principle of irritability, and requires the *immediate* application of a stimulus to the nervo-muscular fibre itself. These three kinds of muscular motion are well known to physiologists; and I believe they are all which have been hitherto pointed out. There is, however, a *fourth*, which subsists, in part, after the voluntary and respiratory motions have ceased, by the removal of the cerebrum and medulla oblongata, and which is attached to the medulla spinalis, ceasing itself when this is removed, and leaving the irritability undiminished. In this kind of muscular motion, the motive influence does not originate in any central part of the nervous system, but at a distance from that centre: it is neither spontaneous in its action, nor direct in its course; it is, on the contrary, *excited* by the application of appropriate stimuli, which are not, however, applied immediately to the muscular or nervo-muscular fibre, but to certain membranous parts, whence the impression is carried to the medulla, *reflected*, and reconducted to the part impressed, or conducted to a part remote from it, in which muscular contraction is effected.

The first three modes of muscular action are known only by actual movements or muscular contractions. But the reflex function exists as a continuous muscular action, as a power presiding over organs not actually in a state of

motion, preserving in some, as the glottis, an open *, in others, as the sphincters, a closed form, and in the limbs, a due degree of equilibrium, or balanced muscular action,—a function, not, I think, hitherto recognised by physiologists.

The three kinds of muscular motion hitherto known may be distinguished in another way. The muscles of voluntary motion and of respiration may be excited by stimulating the nerves which supply them, in any part of their course, whether at their source, as a part of the medulla oblongata or medulla spinalis, or exterior to the spinal canal: the muscles of involuntary motion are chiefly excited by the actual contact of stimuli. In the case of the reflex function alone, the muscles are excited by a stimulus acting mediately and indirectly in a curved and reflex course, along superficial sub-cutaneous or sub-mucous nerves proceeding to the medulla, and muscular nerves proceeding from the medulla. The first three of these causes of muscular motion may act on detached limbs or muscles. The last requires the connexion with the medulla to be preserved entire.

All the kinds of muscular motion may be unduly excited. But the reflex function is peculiar in being excitable into modes of action not previously subsisting in the animal economy, as in the cases of sneezing, coughing, vomiting, &c. The reflex function also admits of being permanently diminished or augmented, and of taking on some other morbid forms, of which I shall treat hereafter.

I shall thus have occasion to speak of the reflex function as the source of equilibrium in the muscular system; as excitable into various actions, which, however familiar, are not constant; and as assuming morbid forms.

Before I proceed to the detail of the experiments upon which this disquisition rests, it may be well to point out several instances in illustration of the various sources and modes of muscular action which have been enumerated. None can be more familiar than the act of swallowing. Yet how complicated is this act! The apprehension of the food by the teeth, the tongue, &c., is voluntary, and cannot, therefore, take place in an animal from which the cerebrum is removed †. The transition of the food over the glottis and along the middle and lower parts of the pharynx depends upon the reflex function: it can take

* See Legallois, Op. cit. p. 176—178.

† Du Système Nerveux, par M. Flourens, Paris 1824, p. 90.

place in animals from which the cerebrum has been removed *, or the ninth pair of nerves divided †; but it requires the connexion with the medulla oblongata to be preserved entire ‡; and the actual contact of some substance which may act as a stimulus §: it is attended by the accurate closure of the glottis, and by the contraction of the pharynx. The completion of the act of deglutition is dependent upon the stimulus immediately impressed upon the muscular fibres of the œsophagus, and is the result of excited irritability.

The example which I have given is one of excited reflex function. The condition of the glottis during respiration, and that of the pharynx and of the sphincters at all times, except during the acts of deglutition, or of excretion, afford equally interesting and familiar examples of the permanent influence of that function. Whilst the nervous connexion between the larynx and the medulla oblongata is preserved entire,—in the rabbit (*Lepus cuniculus*), for example,—the glottis is preserved open, being slightly dilated during each act of inspiration; but if the superior laryngeal nerves be divided, the aperture immediately becomes so much diminished, that a state of excessive dyspnœa is induced. The sphincter ani, on the other hand, remains closed in the decapitated turtle (*Chelonia mydas*), if the lower part of the medulla spinalis be left in its canal; but it becomes immediately relaxed and open, if this part of the nervous system be withdrawn. The action of this muscle depends upon the medulla spinalis, and not upon the brain only.

However plain these observations may have made the fact, that there is a function of the nervous and muscular system distinct from sensation, from the voluntary and respiratory motions, and from irritability, it is right, in every such inquiry as the present, that the statements and reasonings should be made with the experiment, as it were, actually before us. It has already been remarked, that the voluntary and respiratory motions are spontaneous acts, not necessarily re-

* Du Système Nerveux, par M. Flourens, Paris 1824, p. 90.

† The Nervous System, by Charles Bell, F.R.S. 4to ed. 1830. Appendix, p. cxviii.

‡ De l'Usage de l'Epiglotte, par M. Magendie, Paris 1813, pp. 6, 23, &c.

§ This is the reason of our inability to perform the act of swallowing two or three times in rapid succession, without taking something into the mouth, or allowing time for the secretion of a portion of saliva. The reflex function must be excited into action by the contact of a stimulus. The act of swallowing cannot, therefore, be renewed unless some substance, as saliva, be carried into contact with the pharynx. See further, p. 661.

quiring the agency of a stimulus. If, then, an animal can be placed in such circumstances that such motions will certainly not take place, the power of moving remaining, it may be concluded that volition and the motive influence of respiration are annihilated. Now this is effected by removing the cerebrum and the medulla oblongata. These facts are fully proved by the experiments of Legallois and M. Flourens, and by several which I proceed to detail, for the sake of the opportunity afforded by doing so, of stating the argument most clearly.

I divided the spinal marrow of a very lively snake (*Coluber natrix*), between the second and third vertebræ. The movements of the animal were, immediately before, extremely vigorous and unintermitted. From the moment of the division of the spinal marrow, it lay perfectly tranquil and motionless, with the exception of occasional gaspings and slight movements of the head.

It became quite obvious that this state of quiescence would continue indefinitely, were the animal secured from all external impressions.

Being now stimulated, the body began to move with great activity, and continued to do so for a considerable time, each change of position or situation bringing some fresh part of the surface of the animal into contact with the table or other objects, and renewing the application of stimulus.

At length the animal became again quiescent; and being carefully protected from all external impressions, it moved no more, but died in the precise position and form which it had last assumed.

It requires a little manœuvre to perform this experiment successfully: the motions of the animal must be watched, and slowly and cautiously arrested by opposing some soft substance, as a glove or cotton wool; they are by this means gradually lulled into quiescence. If at this moment the figure last assumed be sketched upon paper, and the animal be left, protected from external impressions, it will be found to retain the same identical form when all vitality has ceased.

The slightest touch with a hard substance, the slightest stimulus, will, on the other hand, renew the movements of the animal in an active form. But that this phenomenon does not depend upon sensation, is further fully proved by the facts, that the position last assumed, and the stimuli applied, may be such as would be attended by extreme or continued pain, if the sensibility were undestroyed: in one case the animal remained partially suspended over the acute

edge of the table; in others the infliction of punctures, and the application of a lighted taper, did not prevent the animal, still possessed of active powers of motion, from passing into a state of complete and permanent quiescence.

The same observations were made upon various other animals—the turtle, the viper (*Vipera Berus*), the toad (*Bufo vulgaris*), the frog (*Rana temporaria*), the eft (*Triton cristatus*), &c. It may therefore be stated as a general fact, that if an animal be deprived of the cerebrum and medulla oblongata, and placed under an inverted bell-glass, or otherwise protected from external stimuli, it will not move, however easily it may be excited to motion by external impressions.

I must now solicit the attention of the Society to three important points: it is obvious,

1st, That sensation can act, in inducing muscular motion, only through the medium of volition;

2ndly, That, in the experiments which have been described, volition,—the *will*, and not the *power*, to move, was annihilated;

3rdly, That, in such cases,—volition being destroyed and the agency of sensation excluded,—the influence of external impressions, which might be supposed to induce pain, must have been exerted upon some property of the nervous system different from sensibility.

The absence of spontaneous motions in decapitated animals, proves the privation of volition; and the privation of volition removes all evidence of sensibility in excited motions, and indeed positively excludes its influence. Sensation, volition, and motion, may be viewed as three links of the chain, in the case in which motion is induced by pain. If the second link be destroyed, the *connexion* between the first and third is dissolved. The proof, in fine, that the excited motions which belong to the reflex function are independent of sensation, is precisely of the same character as that by which the motions due to irritability are distinguished from the same principle.

We are hence led to the conclusion that the excited motions of decapitated animals are dependent upon a principle different from sensation and volition; and we are further led to the inquiry—What is the nature of that principle—what the cause of those motions, which remain after sensation and volition are destroyed?

But before I enter upon this question, it is important to show still more distinctly than I have done, the distinction between the movements arising from the reflex function of the medulla oblongata and medulla spinalis, and those arising from irritability itself. If the glottis of an animal be touched, there is an immediate contraction. If the heart be touched, the same phenomenon is observed. What is the difference between the excited movements of these two organs? If the brain be removed, the same events still take place. If the medulla oblongata be removed, the contractions of the stimulated larynx suddenly cease, whilst those of the heart continue as before. The difference consists, then, in the presence of the medulla oblongata, which is essential to the contractions of the larynx, but of which those of the heart are entirely independent. The influence of the stimulus upon the heart is immediate. That of a stimulus applied to the larynx must pass to the medulla oblongata, and be reflected upon the part moved.

It is interesting to compare the excited movements of the glottis and the submaxillary textures, of the sphincter ani and the tail, and of the heart, in these several parts of the recently killed turtle, placed together upon the same table. All continue vigorous for a considerable time, until the medulla oblongata or the medulla spinalis be withdrawn, when the movements of that portion of the respiratory apparatus which is attached to the head, or of the sphincter and tail, cease in an instant.

The reflex function of the medulla is most permanent and apparent to observation in those animals in which the respiration is lowest. The cold-blooded animals, the hybernating animal, and the very young of the warm-blooded, are therefore the subjects in which this function can be best studied. It may be retained, or restored, however, in the adult warm-blooded animal, by retaining the respiration, or by renewing the respiration artificially,—a fact, which constitutes another characteristic of the reflex function, and distinguishes it from irritability, and which is, in my opinion, one of the most remarkable in physiology, and highly worthy of further investigation. These remarks will readily suggest the proper choice of animals, and mode of experiment, for the display of the reflex function. I now proceed to the detail of the various experiments which I have made upon this subject, and shall then deduce the conclusions which appear to flow from them.

II. *Experiments.*

The phenomena of the reflex function, like those of the irritability, are, as I have just stated, more observable in the lower orders of animals, in the very young of the higher orders, and in the state of hybernation. It will be found, however, that the full-grown mammalia are not less distinctly endued with this property of the nervous system, whilst the functions of respiration and circulation are continued.

The first experiment which I made was upon the turtle.

This animal was decapitated in the manner usual with cooks, by means of a knife, which divided the second or third vertebra.

The head being placed upon the table for observation, it was first remarked that the mouth opened and shut, and that the submaxillary integuments descended and ascended, alternately, from time to time, replacing the acts of respiration. I now touched the eye or eyelid with a probe. It was immediately closed: the other eye closed simultaneously. I then touched the nostril with the probe. The mouth was immediately opened widely, and the submaxillary membranes descended. This effect was especially induced on touching the nasal fringes situated just within the anterior part of the maxilla. I passed the probe up the trachea and touched the larynx. This was immediately followed by a forcible convulsive contraction of the muscles annexed to it. Having made and repeated these observations, I gently withdrew the medulla and brain. All the phenomena ceased from that moment. The eye, the nostril, the larynx were stimulated, but no movement followed.

The next observations were made upon the other parts of the animal. The limbs, the tail, were stimulated by a pointed instrument or a lighted taper. They were immediately moved with rapidity. The sphincter was perfectly circular and closed; it was contracted still more forcibly on the application of a stimulus. The limbs and the tail possessed a certain degree of firmness or tone, recoiled on being drawn from their position, and moved with energy on the application of the stimulus. On withdrawing the spinal marrow gently out of its canal, all these phenomena ceased. The limbs were no longer obedient to stimuli, and became perfectly flaccid, having lost all their resilience. The sphincter lost its circular form and its contracted state, becoming lax, flaccid, and shapeless. The tail was flaccid, and unmoved on the application of stimuli.

This experiment affords evidence of many important facts in physiology. It proves that the presence of the medulla oblongata and spinalis is necessary to the contractile function of the eyelids, the sub-maxillary textures, the larynx, the sphincters, the limbs, the tail, on the application of stimuli to the cutaneous surfaces or mucous membranes. It proves the reflex character of this property of the medulla oblongata and spinalis, and the dependence of these motions upon the reflex function. It proves that the tone of the limbs, and the contractile property of the sphincter, depend upon the same reflex function of the medulla spinalis,—effects not hitherto suspected by physiologists.

I must now state that the phenomena which have been detailed subsist in distinct portions of the divided nervous system. If, after severing the head of the turtle, the lower extremities and the tail be separated together, in the manner usual with cooks, the phenomena which I have described are still observed in the distinct and separate portions of the animal. The head, the anterior extremities, and the tail present the movements which have been described, when severally stimulated. The posterior extremities alone were observed to be flaccid and unimpressible by stimuli; and these were found, on examination, to have been separated from their connexion with the spinal marrow.

An interesting experiment demonstrates the powerful influence of the reflex function over the sphincter ani in the turtle. If, after the removal of the tail and the posterior extremities, with the rectum, and of course with a portion of the spinal marrow, water be forced into the intestine, by means of Read's syringe, both the cloaca and the bladder are fully distended before any part of the fluid escapes through the sphincter, which it then does on the use of much force only, and by jerks. The event is very different on withdrawing the spinal marrow: the sphincter being now relaxed, the water flows through it at once in an easy continuous stream, with the application of little force, and without inducing any distension, even of the cloaca.

I was first struck with the phenomena of the reflex function of the spinal marrow in the separated tail of an eft. On being excited by the point of a needle passed lightly over its surface, it contracted and moved as if it still formed a part of an entire animal.

On another occasion, having removed the head of a frog, I divided the spine between the third and fourth vertebræ, and separated the upper portion of the

animal from the lower. There were then the head, the anterior extremities, and the posterior extremities, with their corresponding portions of medulla, as three distinct parts of an animal. Each preserved the reflex function. On touching an eye, it was retracted, and the eyelids closed, whilst similar phenomena were observed simultaneously in the other eye. On removing the medulla, these phenomena ceased. On pinching the toe of one of the anterior extremities, the limb and the opposite limb equally moved. On removing the spinal marrow, this phenomenon also ceased. Precisely similar effects were observed in regard to the posterior extremities.

Similar phenomena are also observed in the snake. If the head be removed, and a pointed instrument or a lighted taper be brought into contact with any part of the surface, it is instantly moved. The motion consists in a flexion of the entire part, and in a concentric movement of the integuments towards the point irritated; so that the muscles situated along the spine, and certain muscles analogous to the panniculus carnosus, are excited to contraction. The extremity of the tail is most impressible. The function which presides over these movements subsisted in every part of the animal separated from the rest, but instantly ceased on removing the spinal marrow.

On touching a point immediately within the teeth of the upper jaw, the larynx was suddenly drawn downwards and closed. These movements could also be excited by touching the nostrils. They ceased on removing the medulla oblongata.

Similar phenomena are seen also in the very young of the mammalia. A rabbit, one day old, was immediately deprived of all voluntary or respiratory motion, with the exception of gaspings, by dividing the spinal marrow near the occiput. Yet the head and the limbs moved, on stimulating the ears or the feet. These movements ceased in a quarter of an hour, but were renewed by artificial respiration. The phenomena were precisely similar after decapitation, hæmorrhage being prevented and artificial respiration maintained. All ceased on removing the medulla oblongata and spinalis.

One of the most remarkable of the phenomena attached to the reflex function in animals, is that presented by those muscles of the hedgehog (*Erinaceus europæus*) by means of which that animal assumes, in certain circumstances, the form and firmness of a ball. The reflex function seems especially to con-

nect the roots of the spines with the muscles. If the animal be examined under the influence of hybernation, the reflex function continues for some hours after the brain is removed; the panniculus carnosus, the limbs, the tail, the larynx, the sphincter ani, remain excitable, and retain a degree of tone. These phenomena cease on removing the medulla spinalis.

The phenomena of the reflex function seen in the panniculus carnosus, and in other muscles of the hedgehog, are also particularly displayed in the very young animal, in which the peculiar movements of this creature are excitable for a considerable time after decapitation, or the division of the spinal marrow, and long after the cessation of the voluntary and respiratory motions, when it is in a languid and dying state.

In the case of the decapitated young hedgehog, after all gasping has ceased, motions of the larynx are still excited on irritating the nostrils, or on irritating the medulla itself; just as the peculiar motions of the trunk are excited on irritating the limbs, tail, or spines,—or the spinal marrow.

Nor are we without evidence that the same principles obtain in the human subject. The condition of the infant born without cerebrum or cerebellum, and breathing from the influence of the medulla oblongata alone, is precisely that of the reflex function, with the addition of respiration. Such a case has been witnessed and described by Mr. Lawrence *. "The child moved briskly at first, but remained quiet afterwards, except when the tumour was pressed, which occasioned general convulsions. It breathed naturally, and was not observed to be deficient in warmth, until its powers declined. I regret that, from a fear of alarming the mother, no attempt was made to see whether it would take the breast: a little food was given it by the hand. It voided urine twice in the first day, and once a day afterwards: it had three dark-coloured evacuations. The medulla spinalis was continued for about an inch above the foramen magnum, swelling out into a small bulb, which formed the soft tumour on the basis of the skull. All the nerves, from the fifth to the ninth, were connected to this." This brief detail is full of interest. The respiration was natural, the medulla oblongata being entire. Swallowing was effected when food was brought into contact with the pharynx; the sphincters performed their functions; the limbs were moved when the skin was first impressed by the

* Medico-Chirurgical Transactions, vol. v. page 166.

atmospheric air. There was no indication of sensation—the child remained quiet after the first brisk movements; and no event is mentioned which could establish the existence of voluntary motion,—the acts of swallowing, and of the expulsion of the urine and fæces, with the functions of the larynx and of the sphincters, belonging distinctly to the reflex function.

M. Lallemand has briefly described a case of anencephalous fœtus*. "J'ai vu, il y a quatre ans, à l'Hôtel-Dieu, un fœtus anencéphale, à terme, ou à peu près, qui vécut trois jours. Pendant tout ce temps il poussa des cris assez forts, exerça des mouvemens de succion toutes les fois qu'il sentit quelque chose entre ses lèvres; mais on fut obligé de le nourrir avec du lait et de l'eau sucrée, parce qu'aucune nourrice ne voulait lui donner le sein. Il exécutait des mouvemens assez étendus des membres thoraciques et abdominaux. Quand on plaçait un corps étranger dans ses mains, il fléchissait les doigts comme pour le saisir; mais en général tous ses mouvemens avaient moins d'énergie que ceux d'un fœtus de même âge.

"Le cerveau et le cervelet manquaient entièrement: il ne restait à la base du crâne que la moëlle allongée et la protubérance annulaire, avec l'origine des nerfs pneumo-gastrique, trifacial et optique. Le tout était recouvert par les débris des os du crâne, des méninges et de la peau."

A similar case is detailed by M. Ollivier†, who remarks—"J'observai l'enfant anencéphale deux heures après sa naissance. Les yeux étaient constamment fermés; il poussait des cris fréquens qu'on calmait facilement en introduisant le petit doigt dans sa bouche: il exerçait alors des mouvemens de succion répétés; il agitait ses membres avec assez de force, et serrait entre ses doigts les corps qu'on plaçait dans ses mains.

"Je le revis au bout de trois heures. Les pieds et les mains étaient devenus violets et froids; la respiration ne s'opérait plus à des intervalles aussi rapprochés; les mouvemens de la moëlle épinière, que j'avais remarqués d'abord, continuaient toujours d'avoir lieu, et suivaient chacune des grandes et longues inspirations qu'il faisait. Les cris étaient moins forts et moins fréquens: on lui donna à diverses reprises de petites cuillerées de vin vieux sucré.

"Insensiblement le refroidissement des extrémités gagna le reste des mem-

* Observations Pathologiques, p. 86.

† Traité de la Moëlle Épinière, ed. 2, Paris 1827, p. 155.

bres et le tronc; la respiration s'opérait à de plus longs intervalles: elle devint convulsive. Cet état persista pendant six ou huit heures; ses cris devinrent plus faibles et plus éloignés, de même que les mouvemens de la respiration, qui étaient accompagnée de convulsions générales, et il mourut dans un véritable état d'asphyxie, après avoir poussé un cri analogue à celui qui résulte du hoquet."

M. Ollivier adds, (p. 161)—"Il n'existait pas ici un seul rudiment de l'encéphale et des prolongemens de la moëlle alongée; la moëlle épinière seule était restée intacte, et cependant cet infant exerçait des succions répétées, et serrait avec assez de force entre ses doigts les corps qu'on plaçait dans sa main; ces mouvemens étaient loin d'être automatiques comme ceux qui agitaient les membres inférieurs."

These cases, in connexion with the preceding one, are full of interest. The peculiar cries, which resemble, in their rationale, the croup-like convulsion from dentition; the closed state of the eyelids; the action of suction excited by the contact of the finger; the closure of the fingers excited by objects placed in the palm of the hand, and the movements of the inferior extremities, in this acephalous infant, are phenomena of the reflex function of the most deeply interesting character.

The following facts are extracted from a letter addressed by Mr. Sweatman to Sir Charles Bell, and published in the "Nervous System"*:—"After the membranes had given way, and the liquor amnii had escaped, the midwife on examining found another membranous bag presenting, which she naturally supposed belonged to a second child, and therefore did not interfere. During the passage of this bag under the os-pubis, it suddenly burst, and the whole of the brain escaped from the opening very much smashed, and hanging together only by its membranes. The child breathed with perfect freedom and cried strongly, rolling its eyes about in a wild, staring manner. It moved its lower extremities freely, and that not from spasm, but obviously in obedience to external impressions. There was no motion whatever of the upper extremities.

"In this state it remained for about three hours, when all motion in the extremities ceased, the eyes became fixed, and the breathing gradually slower, till it ceased altogether, just seven hours after the birth of the child. During

* Appendix, p. cxxxvi.

this time neither urine nor meconium passed, nor had there been any hæmorrhage from the vessels of the brain.

"On examination the occipital bone and the posterior part of several of the cervical vertebræ were found wanting, and their place had been occupied by fluid, surrounded by a membr nous bag; an instance of spina bifida of the neck. The spinal marrow was perfect.

"A somewhat similar case occurred to me about three years ago, when I had occasion from peculiar circumstances to remove the brain of a child through the anterior fontanelle. In that instance, about ten minutes elapsed before its birth, yet it drew a deep inspiration, and would have cried had it not been prevented; and the motions of the lower extremities continued about half an hour, although the whole of the brain had been removed, and a blunt instrument repeatedly thrust down the foramen magnum *."

It is distinctly proved, by this series of observations, that the reflex function exists in the medulla independently of the brain; in the medulla oblongata independently of the medulla spinalis; and in the spinal marrow of the anterior extremities, of the posterior extremities, and of the tail, independently of that of each other of these parts, respectively.

There is a still more interesting and satisfactory mode of performing the experiment: it is to divide the spinal marrow between the nerves of the superior and inferior extremities. We have then two modes of animal life: the first being the assemblage of the voluntary and respiratory powers with those of the reflex function and irritability; the second, the two latter powers only: the first are those which obtain in the perfect animal, the second those which animate the fœtus. The phenomena are precisely what might have been anticipated. If the spinal marrow be now destroyed, the irritability alone remains, —all the other phenomena having ceased.

The spinal marrow of a frog was divided between the anterior and posterior extremities. It was immediately observed that the head and the anterior extremities alone were moved spontaneously and with design, the respiration being performed as before. But the posterior extremities were not paralyzed: they were drawn upwards, and remained perfectly motionless, indeed, unless stimulated; by the application by any stimulus, they were moved with

* See a similar case by Mr. Hammond, in the Medico-Chirurgical Transactions, vol. xii. p. 308.

energy, but once only, and in a manner perfectly peculiar. The stimulus was not felt by the animal, because the head and anterior extremities remained motionless at the time it was applied. Nothing could be more obvious, and indeed striking, than the difference between the phenomena of the functions of sensation and volition observed in the anterior part of the animal, and those of the reflex function in the posterior: in the former there were spontaneous movements with obvious design; in the latter, the mere effect of stimulus.

The same experiment was made upon the toad; but for some reason, probably anatomical, it does not succeed so uniformly in this animal as in the frog.

The experiment was repeated upon a guinea-pig. The effect was an immediate and total paralysis of sensation and voluntary motion in the posterior extremities: there was no expression of pain when they were pinched, nor was there the slightest indication of a power of spontaneous motion: they were dragged along when the animal moved. But they were not unimpressible by stimuli, nor destitute of the power of moving when stimulated: on the contrary, when pinched, they displayed a sort of repeated, hurried motion, altogether peculiar. The power of the sphincters was evidently preserved. In a word, the reflex function remained entire.

In all these experiments the upper part of the animal presented the phenomena of sensation and of spontaneous movements; in the lower, there was total paralysis of these powers; yet the reflex function, the excitability, the firmness of the limbs, and the irritability remained. It now remains to be stated, that the reflex function admits of *exaltation* and of *diminution*.

If a frog be made to swallow a watery solution of strychnine or of opium, or if such a solution of strychnine or opium be applied to the skin, the animal soon becomes affected with symptoms perfectly similar to those of tetanus. The surface becomes highly susceptible to the impression of stimuli, and the muscles of the limbs become affected with continued spasmodic action. The affection is obviously one of augmented reflex function of the medulla. It accordingly ceases instantly on destroying the nervous masses.

A frog made tetanic by opium was decapitated, and divided just below the third vertebra. The eyes were retracted, and no movement could be detected on irritating the eyelids or skin. Both the anterior and posterior extremities remained susceptible, and tetanic, as before: the limbs were moved in the same

spasmodic manner by the same slight impressions. All was changed on removing the brain and spinal marrow. The eyes were no longer retracted. The muscles of the limbs were immoveable under the action of stimuli, and perfectly flaccid, having lost their exalted tone.

Precisely similar phenomena were observed when the frog was made tetanic by opium or strychnine and divided into three portions, the head, the anterior and the posterior extremities; and in the eft made tetanic and divided into the head, anterior and posterior extremities, and tail. Each part remained tetanic, impressible by the slightest touch, and spasmodically contracted on any application of stimulus. The tetanus in each is instantaneously terminated by destroying the corresponding portion of spinal marrow, the head, the limb, or the tail, instantly manifesting a perfectly relaxed and flaccid condition of the muscles. The irritability remains unimpaired.

These facts complete the proof that the phenomena which I have referred to the reflex function, do not depend either upon sensation and volition, or upon irritability. It is plain that the spasmodic actions in tetanus are not voluntary actions, and they obey the same laws as the movements observed in an animal, or parts of an animal, not tetanic, under the influence of stimuli. It is equally plain that phenomena which depended upon excited irritability would not cease whilst that irritability remained unimpaired*.

The phenomena of tetanus, in its effects upon the limbs, enable us to conceive more distinctly than we should otherwise do, the effect of the reflex function in its natural state, in maintaining the due degree of balance and antagonism of the muscles and firmness of the limbs.

If a few drops of dilute hydrocyanic acid be placed upon the tongue of a frog, a state of things the reverse of that just described as the effect of opium or strychnine is induced: the contractions which depend on the reflex function are observed to become less and less energetic and excitable, and at length cease altogether.

* Having observed these facts in connexion with the reflex function, it became a question whether the rigidity of the muscles immediately consequent to death depends upon the same principle. Two rabbits were killed; in one the spinal marrow was destroyed, in the other it was left entire. Both, however, became equally rigid. So that the spasm of death is a mere effect of irritability, and not of the reflex function of the spinal narrow.

Having thus detailed the phenomena of the reflex function, as they are observed in their ordinary and augmented and diminished degrees of force, I shall briefly enumerate some of those *excited* motions observed in various parts of the animal frame, which are obviously referrible to the same function.

The most healthy condition of the reflex function is that, the result of which is the due state of balance between antagonist muscles. But certain excited states of this function can scarcely be viewed as otherwise than healthy: such are—winking when an object touches the eyelid, the singular effect of dashing cold water on the face, and the singular effect of tickling * upon the respiration, sneezing from irritation of the nostrils, cough from that of the larynx, vomiting from that of the pharynx, strangury from irritation of the rectum, and tenesmus from that of the bladder, &c.

The excited reflex function is observed on touching the eye, the nasal fringes, or the larynx, in the separated head of the turtle; and on touching the sphincter, the tail, or the limbs, of the separated lower portion of that animal; in the frog, the lower extremities are sometimes moved with violence even, on the application of a stimulus, after the division of the spinal marrow. All the systems of muscles, therefore, obviously partake of this remarkable action.

It is plain, from the preceding observations, that the reflex function may be viewed as subsisting in its natural state, in its state of general excess or failure, and in its state of momentary and partial excitement.

III. *Pathology.*

There still remains an interesting part of this inquiry. What relation does the reflex function bear to the art of physic? It will soon be seen that it throws a ray of light over some obscure points in medicine. Indeed the study of the reflex function appears to me to reveal and explain a totally new order of facts in pathology, and to lead to a new division of the diseases of the nervous system, coinciding with the different modes of operation of their causes, into those of *centric* and those of *eccentric* origin.

One of the most interesting of medical subjects, in relation to the reflex

* I can readily imagine that tickling may have been carried to such an extent as to interrupt the respiration and prove fatal by asphyxia, as in a recent instance said to have occurred on the Continent.

function, is that of dentition. Dentition is a sort of natural experiment upon this function. The general convulsion, the strabismus, the spasm of the fingers and toes, the croup-like affection of the respiration, the repeated vomitings, the tenesmus, the strangury, the involuntary discharge of urine and of the fæces, from its operation, denote the influence of irritation of the maxillary nerves, through the medium of the medulla, upon the muscles of voluntary and respiratory motion, of the eye, the larynx, the sphincters, &c., in the human subject, and indicate so many arcs of the reflex function. However these *facts* may have been known, their true *rationale* has not been discovered. In all such cases the remedy is, to relieve the part in which the cause is operating. In the present instance the maxillary nerves and vessels are to be relieved by free scarification; the lancet should be used freely, daily, or still more frequently.

The young of other animals, and especially of the feline and canine species, are exceedingly subject to similar effects from dentition, which are not unfrequently fatal. The fatal event is frequently owing to interrupted respiration. In one instance, the asphyxia was averted, in a very young puppy, by artificial respiration, effected by alternate compression and relaxation of the parietes of the thorax.

The reflex function is far more excitable in the very young animal. The second dentition rarely, therefore, induces such affections as the first.

With the effects of dentition in infants, some affections of the adult may be compared, as chorea, some forms of epilepsy, and some forms of asthma. The diseases to which these designations have been given vary exceedingly in different instances; inasmuch as some cases are of centric and others of eccentric origin. One characteristic distinguishes the latter form of the disease,—it usually combines more affections of the reflex function than one. Such a form of epilepsy, for example, combines hickup, or even vomiting, with the epileptic attack. The usual source of those forms of disease is in the intestinal canal, the stomach being irritated by improper diet or the bowels by morbid contents. This division of the subject leads to an important distinction of these cases into those which admit comparatively more easily, and more difficultly, of cure.

Epilepsy is plainly of two kinds: the first has a centric origin in the medulla itself; the second is an affection of the reflex function, the exciting cause being eccentric, and acting chiefly upon the nerves of the stomach or intes-

tines, which consequently form the first part of the reflex arc. The fact of the frequent occurrence of a fit of epilepsy in coitu is very interesting in reference to the reflex function: it distinctly connects these two events; and it affords another instance of an influence exerted, through the medium of this function, between distant parts of the spinal marrow. There is but a step, as it were, from the normal affection of the nervous, muscular, and respiratory systems, in that circumstance, to an attack of epilepsy itself.

The disease termed asthma claims rather more than an incidental notice in this place. True asthma, viz. that form of this disease which occurs in youth, and assumes a distinctly spasmodic form and course, like so many other morbid conditions of the reflex function, frequently arises from gastric or intestinal irritation. It is also frequently excited by the contact of certain powders, as that of ipecacuanha, with the larynx, just as sneezing is induced by similar impressions upon the nostrils. It appears to consist in an action excited, through the reflex function, in the larger bronchia. The influence of the smoke of the stramonium in relieving the attack of asthma is another argument in favour of its being an affection of the reflex function. Indeed, a comparison of the various causes, the mode of attack, the course, and the effects of remedies, in this singular morbid affection, alike denote its relation to this peculiar function.

With the effects of dentition, those of gastric or enteric irritation, in their multiplied forms, may be compared.

Tenesmus and strangury are affections of other arcs of the reflex function.

One circumstance in the pathology of the reflex function is very remarkable. Several forms of the morbid affections of this function occur during the first sleep. This is the case with the croup-like affection arising from dentition, with spasmodic asthma, and with a peculiar painful affection of the rectum, not hitherto described.

Tetanus and hydrophobia appear equally to result from injuries inflicted upon the extremities of certain nerves, by means of which the morbid influence is conveyed to the medulla, whence it is reflected through the motor nerves to the muscular system. As free lancing of the gums in dentition, so the early division of the wounded nerve or amputation in tetanus, has, at once, checked the morbid affection. Is it possible that hydrophobia might be arrested by a

similar procedure? The subject is of intense interest, and deserving of the fullest attention.

Certain poisons, as the strychnine, induce excess in the reflex function; other poisons, as the hydrocyanic acid, destroy it altogether. In both cases the muscular irritability remains perfect and undiminished. It is probably through the medium of the same functions that many other poisons act upon the animal economy.

In a frog, recently killed by strychnine, the irritability of the muscular fibre remained unimpaired,—a proof that the tetanus of strychnine is an exalted condition of the reflex function, and that the consequence is the exhaustion of that function, and not of the irritability. Another frog, destroyed by the hydrocyanic acid, presented similar phenomena of unimpaired irritability on the application of galvanism. In either case, if the animal be placed in water through which a slight galvanic spark is passed, the limbs are immediately and forcibly extended.

The study of the reflex function will doubtless throw an important light upon toxicology, as well as some parts of pathology, and of the causes and treatment of diseases,—subjects which, as they are more immediately connected with medicine, I purpose forthwith to pursue elsewhere.

Diseases of the nervous system, then, may be divided into those which have their origin at the nervous centres, and those which originate at a distance from those centres; and especially in some part of the nervous arc, the function of which has formed the subject of this paper,—into those of *centric* and into those of *eccentric* origin. It is highly probable that the diseases of the latter class are more numerous than they may at first be supposed to be. Chorea, hysteria, tremor, and convulsion have, doubtless, sometimes a centric, sometimes an eccentric origin. In the latter case, the nervous centres may become morbidly affected in the course of the disease, and the appearances after death may mislead the medical inquirer as to the original cause and seat of the disease. But the whole of this investigation must be reserved for the Transactions of another Society. I shall add but one fact more of a medical character in this place.

Legallois appears to have experienced great difficulty in explaining the occurrence of paralysis from disease of the cerebrum, impressed, as he was

that the spinal marrow constituted the source of voluntary motion. He observes, "Quand bien même on n'apercevrait aucun moyen de les concilier, il n'en demeurerait pas moins vrai, d'une part, qu'une affection bornée uniquement au cerveau peut ôter le sentiment et le mouvement volontaire à la moitié du corps, et de l'autre, que le sentiment et le mouvement volontaire peuvent subsister et être entretenus dans un animal décapité. Quelque opposés que ces faits paraissent être, il faut se souvenir que deux faits bien constatés ne peuvent jamais s'exclure l'un l'autre, et que la contradiction qu'on croit y remarquer tient à ce qu'il y a entre eux quelque intermédiaire, quelque point de contact qui nous échappe*." The facts which have been detailed in this paper enable us readily to remove this difficulty, and to account for the paralysis induced by disease of the cerebrum, on one hand, and for the movements of an anencephalous fœtus in utero, or of a decapitated animal, on the other. The paralysis consists in the loss of voluntary motion; the movements of the anencephalous fœtus result from the agency of the reflex function of the medulla spinalis. Legallois' error was that of mistaking the phenomena of the reflex function for sensation and voluntary motion; and his difficulty naturally arose out of this error. There is no real discrepancy between the two orders of facts to which Legallois refers.

The same facts enable us to understand how a perfect action of the sphincters is compatible with paralysis of the limbs from disease of the cerebrum, and even of the higher parts of the medulla spinalis; whilst paralysis of the sphincters is usually conjoined with paralysis of the limbs, arising from disease of the lower part of the spinal marrow. The first intercepts the principle of voluntary motion; the second affects the very seat of the reflex function which presides over the action of the sphincters.

IV. *Inferences.*

I shall now briefly enumerate the inferences which flow from the preceding facts and experiments.

Physiologists have hitherto enumerated only *three* sources or principles of muscular action,—volition, the motive influence of respiration, and irritability.

There is, however, a *fourth* source of muscular motion distinct from any of

* Op. cit. p. 21.

these, though not hitherto distinguished, to which I have ventured to give the designation of *the reflex*.

Volition and the motive influence of respiration are direct in their course, and spontaneous in their action; the former proceeding from the cerebrum, the latter from the medulla oblongata*.

The movements of irritability are the result of the immediate application of a stimulus to the nervo-muscular fibre itself.

The reflex function is different from any of these:

It remains attached to the medulla spinalis, when the cerebrum and the medulla oblongata are removed: it is not direct like volition, or the motive power of respiration.

Its seat is the medulla generally: it ceases when the medulla is removed, leaving the irritability entire: it is not excited immediately, like the movements of irritability, but mediately, in a reflex course, through the medulla, from the part stimulated to the part moved.

In a state of health, the reflex function presides over the orifices and terminations of the internal canals, such as the glottis and the sphincters, preserving the former open, the latter closed; and it maintains the due tone of each muscle, and the due equilibrium of each system of muscles.

When excited, it gives origin to the movements observed in deglutition, or vomiting, sneezing, tenesmus, &c. The fingers passed into the pharynx of a dog, through an incision made between the thyroid cartilage and the os

* M. Flourens seems clearly to have determined that sensation and volition are seated in the cerebrum. Legallois (Œuvres, p. 17,) and he have ascertained that one office of the cerebellum is to regulate the voluntary motions. Legallois and Sir Charles Bell have shown that the medulla oblongata[a] is the source of the respiratory motions. It is now, for the first time, I believe, shown that a peculiar function of the medulla, superadded to its functions as a mere nervous chord, is that of imparting a state of equilibrium to the muscular system, independently of the influence of the organs which originate and regulate the voluntary and respiratory motions. These several functions are separated, and, in a certain degree, isolated, by removing the cerebrum, the cerebellum, and the medulla oblongata in succession; the last stage of the experiment leaves the reflex function alone,—a function which supplies the deficiency left by the investigations of Legallois, M. Flourens, and Sir Charles Bell, and constitutes the complement of the functions of the nervous system.

[a] This discovery of Legallois is amongst the most brilliant in physiology, and obviously presents the nucleus of that, still more splendid, of the system of the respiratory nerves by Sir Charles Bell. Œuvres, pp. 63, &c. The Nervous System, pp. 222, cxxv. &c.

hyoides, excites the act of deglutition*; passed over the root of the tongue or the fauces, it excites the associated actions of the muscles of the larynx and of expiration†, which constitute the act of vomiting.

When morbidly augmented, it constitutes certain forms of disease, as tetanus, hydrophobia, certain forms of tremor, paralysis agitans, chorea, stammering, &c.; when diminished, it induces those forms of tremor observed when the vital powers are enfeebled.

When otherwise morbid, it occasions other forms of disease, as the convulsion, the croup-like respiration, the affection of the sphincters, observed in dentition, the various effects of intestinal irritation, &c.

The effects of the excited reflex function are sometimes observed in a part *near* that irritated, as in the eyelids in winking, in the glottis on inhaling a drop of water or particle of food, in the sphincter ani in dysentery, &c.; sometimes in parts *remote*, as in the irritation of teething when this induces strabismus, convulsion, the croup-like respiration, relaxed sphincters, &c.

However some of the facts detailed in this paper may have been previously known,—and many were so known‡,—they have never been accurately distinguished from sensation and volition, and associated with a peculiar reflex function of the medulla oblongata and medulla spinalis, influencing other organs besides the limbs, and constituting the principle of tone and of a particular series of actions. It has long been known, for example, that the limbs of a decapitated animal moved on being stimulated; but the phenomenon was confounded with sensation and voluntary motion. It has long been known that carbonic acid could not be inhaled through the larynx; but it has not been shown that this phenomenon depends upon the presiding agency of the medulla oblongata; nor has it been distinctly demonstrated that the functions of the sphincter ani, by which the intestinal excretions are retained for a time, is constantly dependent upon a similar agency of the lower part of the medulla spinalis. In like manner, the facts relative to the irritability were altogether known before Glisson and Haller finally separated this principle of motion

* De l'Usage de l'Epiglotte, p. 3.

† See a Memoir by the author on the Mechanism of the Act of Vomiting, in the Journal of the Royal Institution, 1828, Part I., (April to June,) p. 388.

‡ Compare Whytt, Legallois, Mayo, &c.

from sensation and volition, with which, like the reflex function, it had previously been confounded.

An interesting parallel might, indeed, be instituted between the principle of the reflex function and that of the irritability, in regard to their history and degree of importance: their history is the same; for both had been confounded with sensation and voluntary motion*: their importance is precisely the same; for each presides over its own distinct order of functions.

Legallois plainly mistook the reflex function of the medulla for the principle of sensation and voluntary motion; and no physiologist has distinguished its agency, in the function of the larynx and of the sphincters, from the influence of the brain, or from irritability. The view of M. Cruveilhier, that the medulla spinalis is a mere nervous chord, is at variance with all the facts and experiments detailed in the course of this paper.

It is obviously from the mistake which has been pointed out, that Legallois experienced the difficulty expressed in the following words: "Comment se fait-il qu'après la décapitation, les seuls mouvemens inspiratoires soient anéantis et que les autres subsistent? C'est là, à mon sens, un des grands mystères des puissances nerveuses, mystère qui sera dévoilé tôt ou tard, et dont la découverte jettera la plus vive lumière sur le méchanisme des fonctions de cette merveilleuse puissance†." It was impossible to explain this difficulty whilst the movements of the excited reflex function were confounded with those of voluntary motion; but when this distinction is duly made, nothing is more easy. Decapitation removes, in fact, the sources both of voluntary and of respiratory motion; both these kinds of motion consequently cease: but a class of motions still remains, viz. those of the reflex function, attached to the remaining portion of medulla. Thus is the veil raised from this apparent 'mystery'.

As Legallois has confounded the reflex function with the sensibility and voluntary motions, M. Brachet‡ has confounded it with the functions of the ganglionic system, or the sympathetic. The latter physiologist concludes, that whatever function remains after the division of the spinal marrow, in the organs below that division, must be referrible to the influence of the ganglionic system. In this manner he attempts to prove that some parts of the act and function

* Compare Whytt and Legallois.

† Œuvres, pp. 63, 64.

‡ Du Système Nerveux Ganglionaire, p. 246, &c.

of generation, in both sexes, besides the secretions, depend upon this influence; whereas it is certain that they depend upon the lower portion of the medulla spinalis and belong to the reflex function. It is obvious, that, whilst the secretions may depend on the ganglionic system, the act of excretion, and especially the action of the ejaculatory muscles, is an excited act of the reflex function, which has been fully proved to subsist in every portion of the divided medulla spinalis. This view of the subject is greatly confirmed by a comparison of the act alluded to, with that of deglutition (p. 640, note), and others demonstrably belonging to the reflex function. We know that some reptiles remain in coitu after the head is removed. This is then an act of the reflex function alone. It may take place without sensation, as in cases of disease of the medulla spinalis.

I may state, in conclusion, that all the functions of the muscular system which remain after the sources of the motive influence of the voluntary and respiratory motions are removed, with the exception of those of the heart, and other muscles which contract upon the principle of excited irritability, depend upon the reflex function.

The principles of the movements in the animal economy, viewed in an anatomical and functional point of light, may now be enumerated thus:

1. The cerebrum, or the source of the voluntary motions.
2. The medulla oblongata, or the source of the respiratory motions.
3. The medulla spinalis generally, the middle arc of the reflex function.
4. The nervo-muscular fibre, or the seat of the irritability.
5. The sympathetic, or the source of nutrition, of the secretions, &c.

It is not pretended that this arrangement is either strictly accurate or complete. These principles of action are, besides, frequently and variously combined, and much ulterior investigation is required to ascertain the share and fix the limit of each in various compound operations of the animal economy.

The reflex function of the different portions of the medulla presides over their corresponding organs: the medulla oblongata presides over the larynx and the pharynx; the lumbar and sacral portion of the medulla spinalis presides over the sphincter ani, the cervix vesicæ; and the intervening portions of the medulla give tone and equilibrium to the corresponding portions of the muscular system, and what Legallois has so vaguely designated "*life*," to the corresponding regions of the body. But the operation of the reflex function is by

no means confined to parts corresponding to distinct portions of the medulla. The irritation of a given part may, on the contrary, induce contraction in a part very remote: the irritation of teething may induce spasmodic action or relaxation of the sphincters: the irritation of the nostrils, in the case of a young hedgehog, when so languid that voluntary motion and respiration had ceased, induced as energetic contraction of the most distant part of the panniculus carnosus and of the muscles of the posterior extremities, as irritation of the posterior extremities or tail themselves.

It would seem, from what I have observed in the young of the hedgehog and of other animals, when languid, torpid, or *dying*, that the voluntary motions cease first, then the respiratory motions, next those of the excited reflex function, and, lastly, those of the irritability; the last act of the irritability being that which induces the cadaveric rigidity. After all evidence of irritability has ceased, it is probable that the functions of the sympathetic may still continue.

Such is the order, then, in which this series of functions disappear in death; an order which is inverted when the same functions and their appropriate organs gradually came into existence, in the fœtal and natal states, and in the progressive series of the animal kingdom. The movements of the fœtus in utero, are entirely phenomena of the reflex function: they occur in the anencephalous as well as in the perfect fœtus*. This function and the irritability constitute, indeed, the principles of life and motion in the *fœtal state*.

The functions, in *sleep*, seem to be diminished, and that in the same order. This is particularly seen in the deep lethargy of the hedgehog. The animal becomes quiescent; then it nearly ceases to respire; then the action of the panniculus carnosus yields to partial relaxation; lastly, the heart beats with a reptile slowness. In ordinary sleep, the muscles which retain the eye open lose their powers, and the eyelids close by an act of the reflex function, just as they are kept closed in the anencephalous infant. The eye is only partially closed, even during sleep, in cases of extreme languor and exhaustion, with diminished energy of the reflex function. Volition is first impaired, and the eyelids close; the reflex function next fails, and the eyelids close partially only.

It appears probable that the facts of this paper may lead to some important additions to our knowledge of anatomy, by inducing an accurate inquiry into

* See M. Lallemand's Observations Pathologiques, p. 68.

the origin, course, connexion, and distribution of the subcutaneous, or submucous, and muscular nerves, which constitute the arcs of the reflex function. There can be no doubt that a system of nerves takes its origin from the lower portion of the spinal marrow, to supply the sphincters and the organs of generation, which may be compared to those which concentre in the medulla oblongata. The medulla is also, in its whole course, the source of nerves which supply the limbs, the tail, and the panniculus carnosus, in those animals which possess these structures respectively.

It was observed in one frog that the strychnine applied to a single posterior extremity induced general tetanus. General tetanus, in the human subject, is the effect of the local wound of a nerve. These facts demonstrate the strict connexion and unity of the different parts of the nervous system.

The anatomy of the reflex function must be particularly studied in the medulla oblongata; in the portions of the spinal marrow which give origin to the nerves of the anterior and posterior extremities; in that of the intermediate space which supplies the trunk; in that which is the source of the nerves of the sphincters, the ejaculators, &c., and in that which supplies the tail; and, lastly, in reference to the several columns of which the spinal marrow is composed. I think the investigation of the anatomy will, for various reasons, be best pursued in the hedgehog.

It is gratifying to me to state that no part of these experiments has inflicted pain, beyond that of prompt decapitation, or division of the spinal marrow. This is true, at least, if the conclusion be correct, that when the head is removed from the body, sensation and volition cease, whilst the reflex function and the irritability alone continue; and it may be satisfactory to the humane to know that the motions of the eel, for example, after the head is removed, are not motions arising from sensibility, but from another principle, as distinct from feeling as the irritability of the mere nervo-muscular fibre. This fact will suggest the propriety, as well as the means of avoiding such monstrous cruelty as that of skinning eels alive. This will be effectually done by first removing the head, however the animal may afterwards move on the application of stimuli, and *appear to feel*.

V. *Recapitulation.*

To avoid misapprehension, I think it right, in conclusion, very briefly to recapitulate the claims of this paper:

1. Many of the facts which depend upon the reflex function have long been known to physiologists:

2. But these facts only extend to the excited action of the reflex function, seen in the limbs, and even they have been erroneously ascribed to sensation and volition, or instinct:

3. The facts of excited movements of the larynx, pharynx, sphincters, and ejaculators, and of the panniculus carnosus, have not been shown to be allied to these, and to be dependent on the same individual function of the nervous system:

4. It has not been shown that this function, in its natural state, constitutes the principle of equilibrium and tone, in the whole muscular system, and the principle which presides over the orifices and sphincters of the internal canals:

5. And certainly not, that this principle, morbidly affected, constitutes, in its different forms, the diseases arising from dentition, and the diseases termed tetanus, hydrophobia, chorea, paralysis agitans, certain forms of epilepsy, of tremor, of asthma, &c. &c.:

6. Nor that the same individual function is augmented or diminished to a fatal degree, by certain poisons.

7. This series of facts has not been duly associated and shown to belong to *one* particular *order*:

8. The principle of action in this order of facts has not been demonstrated to be at once excited, and reflex, in its operations, to be essentially connected with corresponding portions of the medulla oblongata and medulla spinalis, and to be independent of the brain:

9. Nor has it been clearly distinguished from the other sources and principles of muscular motion existing in the animal economy, viz. volition, the motive influence of respiration, and irritability, or shown to constitute, with the irritability, the principle of life in the fœtal state:

10. The reflex function appears, in a word, to be the *complement* of the functions of the nervous system hitherto known.

I trust it will be found, from this brief recapitulation, that the foregoing paper may have done some little service to physiological science. I consider the subject as but sketched,—the investigation as but just begun. One part of this inquiry is altogether untouched,—the influence of the mind and emotions, and the corresponding parts of the nervous system, upon the organs which are the subjects of the reflex function. The muscles of voluntary and respiratory motion are alike under the influence of the reflex function; and the muscles over which this function more peculiarly presides are impressible through volition and respiration: other muscles, which are especially attached to the reflex function of the lower portion of the medulla spinalis (p. 661), are apparently under the influence of the cerebellum*. Mental emotions modify the reflex function: they induce sickness, relax the sphincters: they also aggravate the diseases of this function, inducing the attacks of epilepsy, of the croup-like convulsion, &c.

* See Serres, Anatomie Comparée du Cerveau, tome ii. p. 601, &c.

XXVII. *On the present Situation of the Magnetic Lines of equal variation, and their Changes on the Terrestrial Surface. By* Peter Barlow, *Esq., F.R.S., Cor. Memb. Inst. France, and of the Imp. and Royal Academies of Petersburgh, Brussels, &c.*

Received May 6,—Read May 9, 1833.

THE great progress which has been made within a few years in establishing the laws of magnetic action, as subsisting between magnets on each other, and of these on iron, leads to a rational expectation that the still unknown and mysterious laws of terrestrial variation may by perseverance be likewise elicited.

This hope has induced me to undertake the task of collating and arranging all the valuable information recorded in several recent and important voyages and journeys of discovery, surveys, &c., undertaken by the British and by some foreign Governments. In all these cases the officers selected to conduct them have been of the highest scientific character: the subject of magnetism has been, during the time of their performance, the favourite pursuit of many highly talented philosophers in all parts of Europe. Instruments of the most perfect description have been employed, and more than ordinary care bestowed upon the magnetic observations.

Many of these have been made in regions, of all others, the most interesting in such an inquiry, namely, in the vicinity of a principal focus of magnetic energy; others are equally important from their extensive range. In the voyage under the command of Captain Beechey, more than 75,000 miles of the earth's surface were traversed, and, throughout, the errors from local attraction were carefully excluded. The surveys of the coast of Africa, America, and New Holland, by Captains Owen and King, and many others which might be enumerated, performed by officers in the British navy, and the circumnavigation of the southern pole by Captain Biscoe, have alone furnished an immense stock

of valuable information; but to these we have to add the voyages by Captain Lutke in the Russian service, of Captain Duperrey in the French service, and the valuable references I have been enabled to obtain through the kindness of Captains Beaufort and Horsburgh, recorded in their respective offices. These together formed such a mass of well-authenticated observations, as seemed to render it very desirable to collect and arrange them, so as at least to furnish a sure foundation for future comparison, if not for immediate investigation.

With regard to the mode of arrangement, the charts of Halley, Yates, Hansteen, &c., naturally led me to the idea of one of the same form, as given in the accompanying engravings (Plates XVII. and XVIII.); but feeling dissatisfied with the great distortion of the lines in the higher latitudes, and the necessary want of continuity on the two sides of the chart, I determined to begin de novo, and to lay the lines all down on a 15-inch globe, where they of course are exhibited in their natural situation, and in regular continuity, the latter condition being only attainable in the latter form; and I extremely regret that I am not able to publish the work in this form, being so much better calculated to elucidate the subject, than any chart that can be constructed. As I was desirous of keeping myself entirely free from any theoretical notions, my object being principally to fix the foundation for future views and comparisons, I have laid down such lines only as are drawn from actual observations, so that where these failed I have left the parts blank; this is chiefly observable about the south pole and over lands, except in Europe, where well observed variations have enabled me to continue them over both land and water. Having thus devoted the oceans to the variation lines, I had intended to have laid down the lines of equal dips upon the land: but after some consideration I have omitted these; they might, however, be introduced without confusing the lines of variation. On the globe I have coloured those oceans in which the variation is east, with a light green; and where it is west, with a light blue: in the same way, if the dip lines were introduced, those parts of the land and continents in which the dip is north, and where it is south, might be distinguished by a similar contrast of colour,—a plan which relieves the eye, and assists the mind in tracing the various configurations of the several lines.

On attentively examining these lines, either in the form of a chart, or on the globe, but particularly on the latter, it must, I think, be acknowledged, not-

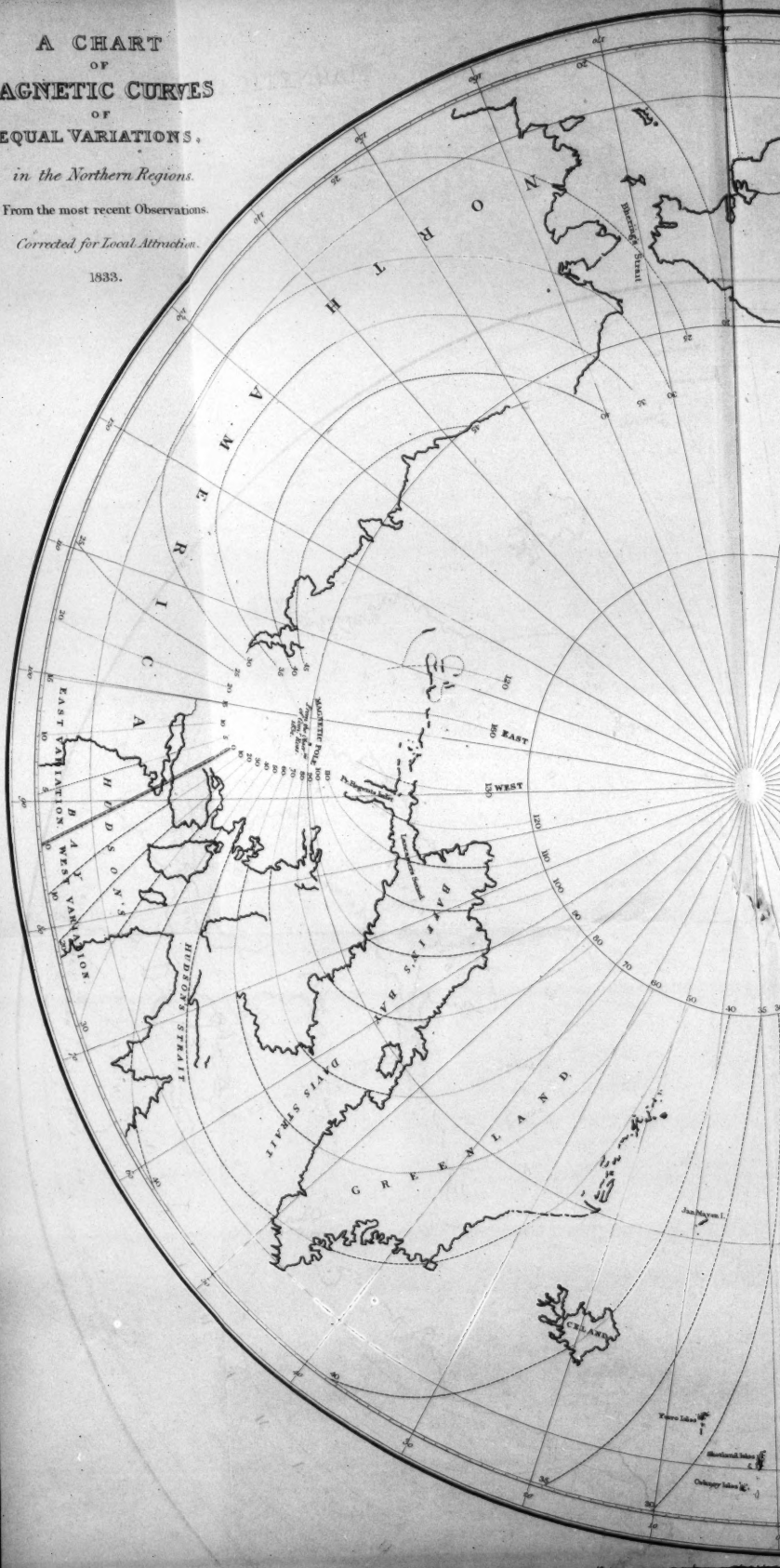
A CHART
OF
MAGNETIC CURVES
OF
EQUAL VARIATIONS,

in the Northern Regions.

From the most recent Observations.

Corrected for Local Attraction.

1833.



COLLATED
AND
ARRANGED
BY
PETER BARLOW, F.R.S.
Corr. Mem. Inst. France.
of the Imperial and Royal Academies
of St. Petersburgh, Brussels, &c. &c.

Drawn by P. Barlow Jun^r

NORTH PACIFIC OCEAN
NORTH AMERICA
HUDSON'S BAY
UNITED STATES
GULF OF MEXICO
CARIBBEAN SEA
WEST INDIES
SOUTH PACIFIC OCEAN
SOUTH AMERICA
SANDWICH ISLANDS
Owhyhee
Mowee
Marquesas Islands
Navigators Isles
Friendly Islands
Society Islands
Otaheite
Low Islands
Dangerous Archip.
Gambiers Groups
Easter I.
Galapagos
Juan Fernandez
Masafuera
Valparaiso
Concepcion
Valdivia
Coquimbo
LIMA
Callao
C. Blanco
Gulf of Guayaquil
Gulf of Choco
Acapulco
Vera Cruz
Havana
Jamaica
Hispaniola
Porto Rico
Barbadoes
Bermudas or Somers Isles
Boston
New York
Philadelphia
WASHINGTON
Charleston
New Orleans
Pensacola
Tortugas
Campeachy
Yucatan
Soccoro I.
C. St Lucas
Port S. Francisco
Monterey
C. Mendocino
Columbia R.
C. Orford or C. Blanco
Nootka Sound
Cook's River
Prince William's Sound
Mount St Elias
Behring's Bay
Kodiak
Sea Otter Bay
Unalaska
Behring's Straits
Kamtschatka
Hudson's Bay
Fort Churchill
York Fort
Severn Factory
C. Henrietta Maria
James's Bay
Moose Fort
Albany Fort
Richmond Gulf
Labrador
Quebec
Gulf of St Lawrence
Cape Breton
Halifax
Newfoundland
Terra Firma
Gulf of Darien
Gulf of St Antonio
Gulf of St George
Port of Ambon
Wallingore
Str. of Magellan
Cape Horn
Staten I.
Falkland Islands
Buenos Ayres
Rio Janeiro
Bahia
Pernambuco
Cape Verd Islands
Longitude West 130 of Greenwich

A CHART
OF
MAGNETIC CURVES
OF
EQUAL VARIATION,
Between the Lat. 60° N. and Lat. 55° S.
From the most recent Observations.
1833.
BY PETER BARLOW, F.R.S.
Cor. Mem. Inst. France.
and of the Imperial and Royal Academies of St. Petersburgh, Brussels, &c. &c.
Drawn by P. Barlow Jun.
WEST VARIATION.
EAST VARIATION
WEST VARIATION
Meridian of Greenwich
Equator or Equinoctial Line
NORTH ATLANTIC OCEAN
SOUTH ATLANTIC OCEAN
EUROPE
AFRICA
AMERICA
INDIA
Gulf of Guinea
Mediterranean Sea
North Sea
Black Sea
Persian Gulf
Arabian Gulf or Red Sea
Azores or Western Islands
Canary Isles
Cape Verde Islands
St. Helena
Isle of Georgia

A CHART
OF
MAGNETIC CURVES
OF
EQUAL VARIATION,
Between the lat. 60° N. and lat. 55° S.
From the most recent Observations.
1833.
BY PETER BARLOW, F.R.S.
Corr. Mem. Inst. France.
and of the Imperial and Royal Academies of St Petersburgh, Brussels, &c. &c.
Drawn by P. Barlow Junr
WEST VARIATION.
EAST VARIATION.
WEST VARIATION.
Meridian of ⊕ Greenwich
NORTH SEA
ATLANTIC OCEAN
SOUTH ATLANTIC OCEAN
INDIAN OCEAN
Gulf of Guinea
Black S.
Arabian Gulf or Red Sea
Persian Gulf
Mozambique Channel
Madagascar
Equator or Equinoctial Line
VARIATION
VARIATION

WEST VARIATION.
WEST VARIATION.
EAST VARIATION.
WEST VARIATION.
EAST VARIATION.
Longitude East 120 of Greenwich
HINDOOSTAN
CALCUTTA
BORNEO
PHILIPPINE ISLANDS
NEW GUINEA
HOLLAND
AUSTRALIA
VAN DIEMEN'S LAND
NEW ZEALAND
NEW CALEDONIA
SEA OF OKHOTSK
KAMTSCHATKA
KURILSKI ISLANDS
YELLOW SEA
JAPAN
COREA
Canton
Macao
Bombay
Madras
Malacca
Java
Sumatra
Celebes
Moluccas
Gilolo
Timor
Solomon Islands
Admiralty Islands
New Ireland
Caroline Islands
Friendly Islands
New Hebrides
Gulf of Carpentaria
Sharks Bay
Swan R.
King George's Sound
Port Jackson
Port Dalrymple
Hobart Town
Gulf of St. Vincent
Encounter B.
Spencer's G.
Maldives
Amsterdam I.
Land's End
Auckland I.
Cape Horn
Cape of Good Hope
Cape Verd
Cape Horn
WEST VARIATION.
EAST VARIATION.
Longitude East 120 of Greenwich

withstanding their extraordinary curvatures, that they exhibit a character which indicates their being dependent on some law, however intricate and mysterious. If the variations were, as has been sometimes supposed, greatly influenced by parts immediately in their vicinity, we could not expect to find that regularity which is observable in so many, if not in all parts: throughout the Atlantic Ocean, for example, there is a continuity and softness of curvature, and unity of character quite inconsistent with such a supposition; still the lines there recorded are the legitimate deductions of a comparison of many hundred observations with each other.

Again, in the Indian Ocean we have a most extraordinary inflection of the curve of no variation, whereby we find, in traversing the earth's equator, that two thirds of it, or 240°, have easterly variation, while only 120° have westerly variation; and here again, in consequence of this extreme anomaly, I have taken particular pains, and have examined an immense number of observations, as recorded both by officers in the British navy, and in the East India Company's ships, with the greatest care, and there is no question whatever that the lines as laid down on the globe are an exact representation of those on the earth; but we see no such sudden interruptions of curvature as must occur if local causes were very influential. I may also remark, that the observations in these seas are by far more accordant and positive in their character than I generally found them in other parts,—a circumstance probably attributable to the very small dip in these seas, and the consequent high intensity of the horizontal needle, which rendered it by position less liable to disturbance from local attractions, and more determinate in its direction.

Another marked peculiarity in this ocean is, that for forty degrees the line of no variation runs nearly parallel to the equator, and then for another forty degrees down a meridian; and as in cases of no variation the magnetic pole, as we commonly understand the term, must be on the meridian of the place, it follows that the pole must also range through forty degrees, or be coincident with the pole of the world; either of which conditions is equally inconsistent with the notion that all these phenomena are due to the action of four or more magnetic poles.

Again, referring to the remarkable curves in the great Pacific Ocean, there is, notwithstanding their peculiar character, no appearance of uncertain and

anomalous attractions: the whole seems to form a system by itself. The lines, instead of extending towards the poles, as in most other parts, return upon themselves in similar, though not in regular figures: and here again I can see no possible position of four poles which can lead to such configuration.

These lines differ very considerably from those of former charts; but they are drawn from a careful examination of observations, not so numerous, certainly, as in some other parts, but still in all probability much exceeding those on which former charts in this ocean have been constructed.

Many other peculiarities will occur to any person carefully examining the several curvatures, particularly that remarkable one found in crossing the Continent of Asia; but as I have not had an opportunity of consulting the original authorities on which these lines are founded, I shall not offer any remark upon them, except to state that they rest on the authority of a most able and indefatigable observer, Professor Hansteen, only that a slight change was rendered necessary by the recent observations of Captain Lutke on the coasts of Nova Zembla and the North of Europe.

The foregoing remarks have reference to the present state of the magnetic lines; but their progressive change of situation and configuration is another important feature in terrestrial magnetism. The first notice I can find of the variation itself occurs in the year 1269, in a letter from Petri Peregrini to a friend, where the author states that after several careful experiments he found it amounted to 5° east in Italy; but the method of observation at that time was very unsatisfactory: it consisted only in touching an iron needle with the loadstone, and observing its bearing before its power was lost. In 1580 the variation was certainly 11¼° east in London: about 1658 it was zero, the needle pointing then due north. In 1700 it was about 8 degrees west, at which time it was zero on the coast of America in the vicinity of New York, and it has remained at the latter place nearly the same ever since.

It follows, therefore, that about the year 1660, the line of no variation must have crossed the Atlantic nearly at right angles to the meridians, as it does now in the Indian Ocean.

From that time it has been gradually descending towards the south and west, and at present crosses some way inland on the eastern point of South America.

We have not such early authority for that line of no variation which passes through Australia, but since that country has been pretty well known, at least for 60 years, very little if any change has taken place, and it seems probable the variation about this spot is as fixed as in that on the coast of America.

I refer to these two cases because they differ very considerably from all others in which a line of no variation has been known to cross; the motion for some years before and after the actual passage of that line being generally very rapid, whereas in these it is stationary or nearly so. Thus in London, the variation was 11° 15′ east in 1580; in 1658 the line of no variation passed our meridian, and in 1698 it was about 8° west, giving a change of 20° in a little more than 100 years; and the same is observed in all other places where the passage of the line is well determined, while in the two places referred to, it has experienced no change, or very little, in the one, for more than 130 years, and in the other probably for as long a time, but certainly for more than 60 years.

In the West Indies, the Bermudas, and a few other places, where the variation is small, the change has also been very inconsiderable; but I believe no case occurs where the variation is large and stationary,—a peculiarity which ought to be well considered in attempting a theory of these motions. Another circumstance equally remarkable is, that in all cases in which sufficient registers of variation have been made, and where the motion or change has been considerable, we may always reduce that motion to a circular rotation of a certain assumed magnetic pole about the pole of the earth: that is, we may, by assuming for each place its own pole, revolving at a given uniform rate, compute the variation of the needle at any period so as to agree very nearly with observation.

Churchman, in his Atlas, I think, was the first to make this assumption, and to compute the consequent variations in London for every ten years from 1622 to 1800; which he afterwards compared with actual observed variations, and in every case the error between the two is very inconsiderable.

In the second edition of my Essay on Magnetic Attractions, I have made a similar comparison, not by assuming the place of the pole, but by computing it from the dip and variation; and the errors or differences in this case, though certainly not so small, are still by no means considerable.

In the Article "Magnetism" in the Encyclopædia Metropolitana, I have

made similar computations for Paris and Copenhagen, the only two places besides London where observations are recorded for any length of time, and in both these the agreements between the computed and observed variations are still more approximate than in London.

Now it must be considered very extraordinary that such remarkable agreements as these should obtain in three places, between the computed and observed variations, through more than thirty degrees of change, or for a period of 170 years, if the hypothesis of a polar revolution were not founded in fact. Assuming then, that, from whatever cause it may proceed, such a revolution does take place, how are we to account for those stationary, or nearly stationary, points of no variation to which reference has been made?

The only reply to this question appears to be, that there is no determinate pole to which all needles point, but that every place has its own particular pole and polar revolution, governed probably by some one general but at present unknown cause. Should this be the case, and the magnetic pole of any place be nearly coincident with the terrestrial pole, the line of no variation, notwithstanding the rotation, must remain nearly stationary; but such stationary position is impossible where the variation is considerable, although the change ought to be very slow on this hypothesis while it is passing through its maximum.

I have offered these few remarks without any intention of their being considered as illustrations of a particular theory. My only object has been in this undertaking to give an exact representation, as far as it was possible, of the present state of terrestrial magnetism, and in this I have every reason to hope I have succeeded.

In the performance of this task, which has required several months of close application, I have been greatly assisted by my son, who has executed with great accuracy the whole of the graphical part, and aided in the comparison of many thousand observations; and I shall be most happy if our joint labour should furnish the requisite data for either a present or future development of those mysterious laws which govern the magnetism of the terrestrial globe,—an object as interesting in philosophy as it is important in navigation.

Woolwich,
May 1st, 1833.

November 18*th*, 1833.

P.S. Since this paper was read, and the globe and chart referred to in this article were drawn, Captain Ross has returned from his long and adventurous voyage. It will be seen by a reference to the polar chart, that, although I was enabled to lay down the curves of equal variation to within a few degrees of their point of concurrence, yet they are all terminated before arriving at it, for want of sufficient data. These are now supplied; and it is very gratifying to me, as I hope it may be also to Captain Ross and to Commander James Ross, to find that the very spot in which they have found the needle perpendicular, —that is, the pole itself,—is precisely that point on my globe and chart in which, by supposing all the lines to meet, the several curves would best preserve their unity of character, both separately, and conjointly as a system. By some delay in engraving the chart, I am able to add to it the exact place of the pole, as obtained from the numerous and admirably arranged observations of Commander Ross, which I have had the pleasure and satisfaction of examining, and which I hope, in the ensuing session, will be laid before the Royal Society.

XXVIII. *Experimental Researches in Electricity.—Fifth Series.* By MICHAEL FARADAY, *D.C.L., F.R.S. &c., Fullerian Prof. Chem. Royal Institution, Corr. Memb. Royal and Imp. Acad. of Sciences, Paris, Petersburgh, Florence, Copenhagen, Berlin, &c. &c.*

Received June 18,—Read June 20, 1833.

§ 11. *On Electro-chemical Decomposition.* ¶ i. *New conditions of Electro-chemical Decomposition.* ¶ ii. *Influence of Water in Electro-chemical Decomposition.* ¶ iii. *Theory of Electro-chemical Decomposition.*

§ 11. *On Electro-chemical Decomposition.*

450. I HAVE in a recent series of these Researches (265.) proved (to my own satisfaction, at least,) the identity of electricities derived from different sources, and have especially dwelt upon the proofs of the sameness of those obtained by the use of the common electrical machine and of the voltaic battery.

451. The great distinction of the electricities obtained from these two sources is the very high tension to which the small quantity obtained by aid of the machine may be raised, and the enormous quantity (371. 376.) in which that of comparatively low tension, supplied by the voltaic battery, may be procured; but as their actions, whether magnetical, chemical, or of any other nature, are essentially the same (360.), it appeared evident that we might reason from the former as to the manner of action of the latter; and it was to me a probable consequence, that the use of electricity of such intensity as that afforded by the machine, would, when applied to effect and elucidate electro-chemical decomposition, show some new conditions of that action, evolve new views of the internal arrangements and changes of the substances under decomposition, and perhaps give efficient powers over matter as yet undecomposed.

452. For the purpose of rendering the bearings of the different parts of this series of researches more distinct, I shall divide it into several heads.

¶ i. *New conditions of Electro-chemical Decomposition.*

453. The tension of machine electricity causes it, however small in quantity, to pass through any length of water, solutions, or other substances classing with these as conductors, as fast as it can be produced, and therefore, in relation to quantity, as fast as it could have passed through much shorter portions of the same conducting substance. With the voltaic battery the case is very different, and the passing current of electricity supplied by it suffers serious diminution in any substance, by considerable extension of its length, but especially in such bodies as those mentioned above.

454. I endeavoured to apply this facility of transmitting the current of electricity through any length of a conductor, to an investigation of the transfer of the elements in a decomposing body, in contrary directions, towards the poles. The general form of apparatus used in these experiments has been already described (312. 316.); and also a particular experiment (319.), in which, when a piece of litmus paper and a piece of turmeric paper were combined and moistened in solution of sulphate of soda, the point of the wire from the machine (representing the positive pole) put upon the litmus paper, and the receiving point from the discharging train (292. 316.), representing the negative pole, upon the turmeric paper, a very few turns of the machine sufficed to show the evolution of acid at the former, and alkali at the latter, exactly in the manner effected by a volta-electric current.

455. The pieces of litmus and turmeric paper were now placed each upon a separate plate of glass, and connected by an insulated string four feet long, moistened in the same solution of sulphate of soda: the terminal decomposing wire points were placed upon the papers as before. On working the machine, the same evolution of acid and alkali appeared as in the former instance, and with equal readiness, notwithstanding that the places of their appearance were four feet apart from each other. Finally, a piece of string, seventy feet long, was used. It was insulated in the air by suspenders of silk, so that the electricity passed through its entire length: decomposition took place exactly as in former cases, alkali and acid appearing at the two extremities in their proper places.

456. Experiments were then made both with sulphate of soda and iodide of potassium, to ascertain if any diminution of decomposing effect was pro-

duced by such great extension of the moist conductor or body under decomposition; but whether the contact of the decomposing point connected with the discharging train was made with turmeric paper touching the prime conductor, or with other turmeric paper connected with it through the seventy feet of string, the spot of alkali for an equal number of turns of the machine had equal intensity of colour. The same results occurred at the other decomposing wire, whether the salt or the iodide were used; and it was fully proved that this great extension of the distance between the poles produced no effect whatever on the amount of decomposition, provided the same *quantity* of electricity were passed in both cases (377.).

457. The negative point of the discharging train, the turmeric paper, and the string were then removed; the positive point was left resting upon the litmus paper, and the latter touched by a piece of moistened string held in the hand. A few turns of the machine evolved acid at the positive point as freely as before.

458. The end of the moistened string, instead of being held in the hand, was suspended by glass in the air. On working the machine the electricity proceeded from the conductor through the wire point to the litmus paper, and thence away by the intervention of the string to the air, so that there was (as in the last experiment,) but one metallic pole; still acid was evolved there as freely as in any former case.

459. When any of these experiments were repeated with electricity from the negative conductor, corresponding effects were produced whether one or two decomposing wires were used. The results were always constant, being considered in relation to the *direction* of the electric current.

460. These experiments were varied so as to include the action of only one metallic pole, but that not the pole connected with the machine. Turmeric paper was moistened in solution of sulphate of soda, placed upon glass, and connected with the discharging train (292.) by a decomposing wire (312.); a piece of wet string was hung from it, the lower extremity of which was brought opposite a point connected with the positive prime conductor of the machine. The machine was then worked for a few turns, and alkali immediately appeared at the point of the discharging train which rested on the turmeric paper. Corresponding effects took place at the negative conductor of a machine.

461. These cases are abundantly sufficient to show that electro-chemical de-

composition does not depend upon the simultaneous action of two metallic poles, since a single pole might be used, decomposition ensue, and one or other of the elements liberated, pass to the pole, according as it was positive or negative. In considering the course taken by, and the final arrangement of, the other element, I had little doubt that I should find it had receded towards the other extremity, and that the air itself had acted as a pole, an expectation which was fully confirmed in the following manner.

462. A piece of turmeric paper, not more than 0·4 of an inch in length and 0·05 of an inch in width, was moistened with sulphate of soda and placed upon the edge of a glass plate opposite to, and about two inches from, a point connected with the discharging train (Plate XIX. fig. 1.); a piece of tinfoil, resting upon the same glass plate, was connected with the machine, and also with the turmeric paper, by a decomposing wire *a* (312). The machine was then worked, the positive electricity passing into the turmeric paper at the point *p*, and out at the extremity *n*. After forty or fifty turns of the machine, the extremity *n* was examined, and the two points or angles found deeply coloured by the presence of free alkali (fig. 2.).

463. A similar piece of litmus paper, dipped in solution of sulphate of soda *n*, fig. 3, was now supported upon the end of the discharging train *a*, and its extremity brought opposite a point *p*, connected with the conductor of the machine. After working the machine for a short time, acid was developed at both the corners towards the point, i. e. at both the corners receiving the electricities from the air. Every precaution was taken to prevent this acid from being formed by sparks or brushes passing through the air (322.); and these, with the accompanying general facts, are sufficient to show that the acid was really the result of electro-chemical decomposition (466.).

464. Then a long piece of turmeric paper, large at one end and pointed at the other, was moistened in the saline solution, and immediately connected with the conductor of the machine, so that its pointed extremity was opposite a point upon the discharging train. When the machine was worked, alkali was evolved at that point; and even when the discharging train was removed, and the electricity left to be diffused and carried off altogether by the air, still alkali was evolved where the electricity left the turmeric paper.

465. Arrangements were then made in which no metallic communication

with the decomposing matter was allowed, but both poles (if they might now be called by that name,) formed of air only. A piece of turmeric paper *a*, fig. 4, and a piece of litmus paper *b*, were dipped in solution of sulphate of soda, put together so as to form one moist pointed conductor, and supported on wax between two needle points, one *p* connected by a wire with the conductor of the machine, and the other, *n*, with the discharging train. The interval in each case between the points was about half an inch: the positive point *p* was opposite the litmus paper; the negative point *n* opposite the turmeric. The machine was then worked for a time, upon which evidence of decomposition quickly appeared, for the point of the litmus *b* became reddened from acid evolved there, and the point of the turmeric *a* red from a similar and simultaneous evolution of alkali.

466. Upon turning the paper conductor round, so that the litmus point should now give off the positive electricity, and the turmeric point receive it, and working the machine for a short time, both the red spots disappeared, and as on continuing the action of the machine no red spot was re-formed at the litmus extremity, it proved that in the first instance (463.) the effect was not due to the action of brushes or mere electric discharges causing the formation of nitric acid from the air (322.).

467. If the combined litmus and turmeric paper in this experiment be considered as constituting a conductor independent of the machine or the discharging train, and the final places of the elements evolved be considered in relation to this conductor, then it will be found that the acid collects at the *negative* or receiving end or pole of the arrangement, and the alkali at the *positive* or delivering extremity.

468. Similar litmus and turmeric paper points were now placed upon glass plates, and connected by a string six feet long, both string and paper being moistened in solution of sulphate of soda; a needle point connected with the machine was brought opposite the litmus paper point, and another needle point connected with the discharging train brought opposite the turmeric paper. On working the machine, acid appeared on the litmus, and alkali on the turmeric paper; but the latter was not so abundant as in former cases, for much of the electricity passed off from the string into the air, and diminished the quantity discharged at the turmeric point.

469. Finally, a series of four small compound conductors, consisting of litmus and turmeric paper (fig. 5.) moistened in solution of sulphate of soda, were supported on glass rods, in a line at a little distance from each other, between the points *p* and *n* of the machine and discharging train, so that the electricity might pass in succession through them, entering in at the litmus points *b*, *b*, and passing out at the turmeric points *a*, *a*. On working the machine carefully, so as to avoid sparks and brushes (322.), I soon obtained evidence of decomposition in each of the moist conductors, for all the litmus points exhibited free acid, and the turmeric points equally showed free alkali.

470. On using solutions of iodide of potassium, acetate of lead, &c., similar effects were obtained; but as they were all consistent with the results above described, I refrain from describing the appearances minutely.

471. These cases of electro-chemical decomposition are in their nature exactly of the same kind as those effected under ordinary circumstances by the voltaic battery, notwithstanding the great differences as to the presence or absence, or at least as to the nature of the parts usually called poles; and also of the final situation of the elements eliminated at the boundary electrified surfaces (467.). They indicate at once an internal action of the parts suffering decomposition, and appear to show that the power which is effectual in separating the elements is exerted there, and not at the poles. But I shall defer the consideration of this point for a short time (493. 518.), that I may previously consider another supposed condition of electro-chemical decomposition *.

* I find (since making and describing these results,) from a note to Sir HUMPHRY DAVY'S paper in the Philosophical Transactions, 1807, p. 31, that that philosopher, in repeating WOLLASTON'S experiment of the decomposition of water by common electricity (327. 330.), used an arrangement somewhat like some of those I have described. He immersed a guarded platina point connected with the machine in distilled water, and dissipated the electricity from the water into the air by moistened filaments of cotton. In this way he states that he obtained oxygen and hydrogen *separately* from each other. This experiment, had I known of it, ought to have been quoted in an earlier series of these Researches (342.); but it does not remove any of the objections I have made to the use of WOLLASTON'S apparatus as a test of true chemical action (331.).

¶ ii. *Influence of Water in Electro-chemical Decomposition.*

472. It is the opinion of several philosophers, that the presence of water is essential in electro-chemical decomposition, and also for the evolution of electricity by the voltaic battery itself. As the decomposing cell is merely one of the cells of the battery, into which particular substances are introduced for the purpose of experiment, it is probable that what is an essential condition in the one case is more or less so in the other. The opinion, therefore, that water is necessary to decomposition, may have been founded on the statement made by Sir HUMPHRY DAVY, that "there are no fluids known, except such as contain water, which are capable of being made the medium of connexion between the metals or metal of the voltaic apparatus*:" and again, "when any substance rendered fluid by heat, consisting of *water*, oxygen, and inflammable or metallic matter, is exposed to those wires, similar phenomena (of decomposition) occur†."

473. This opinion has, I think, been shown by other philosophers not to be accurate, though I do not know where to refer for a contradiction of it. Sir HUMPHRY DAVY himself said in 1801‡, that dry nitre, caustic potash and soda are conductors of galvanism when rendered fluid by a high degree of heat; but he must have considered them, or the nitre at least, as not suffering decomposition, for the statements above were made by him eleven years subsequently. In 1826 he also pointed out, that bodies not containing water, as *fused litharge* and *chlorate of potassa*, were sufficient to form, with platina and zinc, powerful electromotive circles§; but he is here speaking of the *production* of electricity in the pile, and not of its effects when evolved; nor do his words at all imply that any correction of his former distinct statements relative to *decomposition* was required.

474. I may refer to the last series of these Experimental Researches (380. 402.) as setting the matter at rest, by proving that there are hundreds of bodies equally influential with water in this respect. That amongst binary compounds, oxides, chlorides, iodides, and even sulphurets (402.) were effective; and

* Elements of Chemical Philosophy, p. 169, &c.
† Ibid. pp. 144, 145.
‡ Journal of the Royal Institution, 1802, p. 53.
§ Philosophical Transactions, 1826, p. 406.

that amongst more complicated compounds, cyanides and salts, of equal efficacy, occurred in great numbers (402.).

475. Water, therefore, is in this respect merely one of a very numerous class of substances, instead of being the *only one* and *essential*; and it is of that class one of the worst as to its capability of facilitating conduction and suffering decomposition. The reasons why it obtained for a time an exclusive character which it so little deserved are evident, and consist, in the general necessity of a fluid condition (394.); in its being the *only one* of this class of bodies existing in the fluid state at common temperatures; its abundant supply as the great natural solvent; and its constant use in that character in philosophical investigations, because of its having less interfering, injurious, or complicating action upon the bodies, either dissolved or evolved, than any other substance.

476. The analogy of the decomposing or experimental cell to the other cells of the voltaic battery, renders it nearly certain that any of those substances which are decomposable when fluid, as described in my last paper (402.), would, if they could be introduced between the metallic plates of the pile, be equally effectual with water, if not more so. Sir HUMPHRY DAVY found that litharge and chlorate of potassa were thus effectual*. I have constructed various voltaic arrangements, and found the above conclusion to hold good. When any of the following substances in a fused state were interposed between copper and platina, voltaic action more or less powerful was produced. Nitre; chlorate of potassa; carbonate of potassa; sulphate of soda; chloride of lead, of sodium, of bismuth, of calcium; iodide of lead; oxide of bismuth; oxide of lead: the electric current was in the same direction as if acids had acted upon the metals. When any of the same substances, or phosphate of soda, were made to act on platina and iron, still more powerful voltaic combinations of the same kind were produced. When either nitrate of silver or chloride of silver was the fluid substance interposed, there was voltaic action, but the electric current was in the reverse direction.

¶ iii. *Theory of Electro-chemical Decomposition.*

477. The extreme beauty and value of electro-chemical decompositions have given to that power which the voltaic pile possesses of causing their occur-

* Philosophical Transactions, 1826, p. 406.

rence an interest surpassing that of any other of its properties; for the power is not only intimately connected with the continuance, if not the production, of the electrical phenomena, but has furnished us with the most beautiful demonstrations of the nature of many compound bodies; has in the hands of BECQUEREL been employed in compounding bodies; has given us several new substances, and sustains us with the hope that when thoroughly understood it will produce many more.

478. What may be considered as the general facts of electro-chemical decomposition are agreed to by nearly all who have written on the subject. They consist in the separation of the decomposable substance acted upon into its proximate or sometimes ultimate principles, whenever both poles of the pile are in contact with that substance in a proper condition; in the evolution of these principles at distant points, i. e. at the poles of the pile where they are either finally set free or enter into union with the substance of the poles; and in the constant determination of the evolved elements or principles to particular poles according to certain well ascertained laws.

479. But the views of men of science vary much as to the nature of the action by which these effects are produced; and as it is certain that we shall be better able to apply the power when we really understand the manner in which it operates, this difference of opinion is a strong inducement to further inquiry. I have been led to hope that the following investigations might be considered, not as an increase of that which is doubtful, but a real addition to this branch of knowledge.

480. It will be needful that I briefly state the views of electro-chemical decomposition already put forth, that their present contradictory and unsatisfactory state may be seen before I give that which seems to me more accurately to agree with facts; and I have ventured to discuss them freely, trusting that I should give no offence to their high-minded authors; for I felt convinced that if I were right, they would be pleased that their views should serve as stepping-stones for the advance of science, and that if I were wrong, they would excuse the zeal which misled me, since it was exerted for the service of that great cause whose prosperity and progress they have desired.

481. GROTTHUSS, in the year 1805, wrote expressly on the decomposition of

liquids by voltaic electricity*. He considers the pile as an electric magnet, i. e. as an *attractive* agent; the poles having *attractive* and *repelling* powers. The pole from whence resinous electricity issues attracts hydrogen and repels oxygen, whilst that from which vitreous electricity proceeds attracts oxygen and repels hydrogen; so that each of the elements of a particle of water, for instance, is subject to an attractive and a repulsive force, acting in contrary directions, the centres of action of which are reciprocally opposed. The action of each force in relation to a molecule of water situated in the course of the electric current is in the inverse ratio of the square of the distance at which it is exerted, thus giving (it is stated) for such a molecule a *constant force*†. He explains the appearance of the elements at a distance from each other by referring to a succession of decompositions and recompositions occurring amongst the intervening particles‡, and he thinks it probable that those which are about to separate at the poles unite to the two electricities there, and in consequence become gases§.

482. Sir HUMPHRY DAVY's celebrated Bakerian Lecture on some chemical agencies of electricity was read in November 1806, and is almost entirely occupied in the consideration of *electro-chemical decompositions*. The facts are of the utmost value, and, with the general points established, are universally known. The mode of action by which the effects take place is stated very generally, so generally, indeed, that probably a dozen precise schemes of electro-chemical action might be drawn up, differing essentially from each other, yet all agreeing with the statement there given.

483. When Sir HUMPHRY DAVY uses more particular expressions, he seems to refer the decomposing effects to the attractions of the poles. This is the case in the "general expression of facts" given at pp. 28 and 29 of the Philosophical Transactions for 1807, also at p. 30. Again, at p. 160 of the Elements of Chemical Philosophy, he speaks of the great attracting powers of the surfaces of the poles. He mentions the probability of a succession of decompositions and recompositions throughout the fluid,—agreeing in that respect with GROTTHUSS‖;

* Annales de Chimie, 1806, tom. lviii. p. 64.

† Ibid. pp. 66, 67, also tom. lxiii. p. 20.

‡ Ibid. tom. lviii. p. 68, tom. lxiii. p. 20.

§ Ibid. tom. lxiii. p. 34.

‖ Philosophical Transactions, 1807, pp. 29, 30.

and supposes that the attractive and repellent agencies may be communicated from the metallic surfaces throughout the whole of the menstruum*, being communicated from *one particle to another particle of the same kind*†, and diminishing in strength from the place of the poles to the middle point, which is necessarily neutral‡. In reference to this diminution of power at increased distances from the poles, he states that in a circuit of ten inches of water, solution of sulphate of potassa placed four inches from the positive pole, did not decompose; whereas when only two inches from that pole, it did render up its elements§.

484. When in 1826 Sir Humphry Davy wrote again on this subject, he stated that he found nothing to alter in the fundamental theory laid down in the original communication ‖, and uses the terms attraction and repulsion apparently in the same sense as before ¶.

485. Messrs. Riffault and Chompré experimented on this subject in 1807. They came to the conclusion that the voltaic current caused decompositions throughout its whole course in the humid conductor, not merely as preliminary to the recompositions spoken of by Grotthuss and Davy, but producing final separation of the elements in the *course* of the current, and elsewhere than at the poles. They considered the *negative* current as collecting and carrying the acids, &c., to the *positive* pole, and the *positive* current as doing the same duty with the bases, and collecting them at the *negative* pole. They likewise consider the currents as *more powerful* the nearer they are to their respective poles, and state that the positive current is *superior* in power to the negative current**.

486. M. Biot is very cautious in expressing an opinion as to the cause of the separation of the elements of a compound body††. But as far as the effects can be understood, he refers them to the opposite electrical states of the portions of the decomposing substance in the neighbourhood of the two poles. The fluid is most positive at the positive pole; that state gradually diminishes to the middle distance, where the fluid is neutral or not electrical; but from thence to the negative pole it becomes more and more negative‡‡. When a particle of salt

* Philosophical Transactions, 1807, p. 39. † Ibid. p. 29. ‡ Ibid. p. 42.
§ Ibid. p. 42. ‖ Ibid. 1826, p. 383. ¶ Ibid. pp. 389, 407, 415.
** Annales de Chimie, 1807, tom. lxiii. p. 83, &c.
†† Précis Elémentaire de Physique, 3me edition, 1824, tom. i. p. 641. ‡‡ Ibid. p. 637.

is decomposed at the negative pole, the acid particle is considered as acquiring a negative electrical state from the pole stronger than that of the surrounding *undecomposed* particles, and is therefore repelled from amongst them, and from out of that portion of the liquid towards the positive pole, towards which also it is drawn by the attraction of the pole itself and the particles of positive *undecomposed* fluid around it *.

487. M. Biot does not appear to admit the successive decompositions and recompositions spoken of by Grotthuss, Davy, &c. &c.; but seems to consider the substance whilst in transit as combined with, or rather attached to, the electricity for the time †, and though it communicates this electricity to the surrounding undecomposed matter with which it is in contact, yet it retains during the transit a little superiority with respect to that kind which it first received from the pole, and is, by virtue of that difference, carried forward through the fluid to the opposite pole ‡.

488. This theory implies that decomposition takes place at both poles upon distinct portions of fluid, and not at all in the intervening parts. The latter serve merely as imperfect conductors, which, assuming an electric state, urge particles electrified more highly at the poles through them in opposite directions, by virtue of a series of ordinary electrical attractions and repulsions §.

489. M. A. de la Rive investigated this subject particularly, and published a paper on it in 1825 ‖. He thinks those who have referred the phenomena to the attractive powers of the poles, express the fact generally, rather than give any explication of it. He considers the results as due to an actual combination of the elements, or rather of half of them, with the electricities passing from the poles in consequence of a kind of play of affinities between the matter and electricity ¶. The current from the positive pole combining with the hydrogen, or the bases it finds there, leaves the oxygen and acids at liberty, but carries the substances it is united with across to the negative pole, where, because of the peculiar character of the metal as a conductor **, it is separated from them, entering the metal, and leaving the hydrogen or bases upon its surface. In the same manner the electricity from the negative pole sets the

* Précis Elémentaire de Physique, 3me edition, 1824, tom. i. pp. 641, 642.

† Ibid. p. 636. ‡ Ibid. p. 642. § Ibid. pp. 638, 642.

‖ Annales de Chimie, tom. xxviii. p. 190. ¶ Ibid. pp. 200, 202. ** Ibid. p. 202.

hydrogen and bases which it finds there, free, but combines with the oxygen and acids, carries them across to the positive pole, and there deposits them *. In this respect M. DE LA RIVE's hypothesis accords in part with that of MM. RIFFAULT and CHOMPRÉ (485.).

490. M. DE LA RIVE considers the portions of matter which are decomposed to be those contiguous to *both* poles †. He does not admit with others the successive decompositions and recompositions in the whole course of the electricity through the humid conductor ‡, but thinks the middle parts are in themselves unaltered, or at least serve only to conduct the two contrary currents of electricity and matter which set off from the opposite poles §. The decomposition, therefore, of a particle of water, or a particle of salt, may take place at either pole, and when once effected, it is final for the time, no recombination taking place, except the momentary union of the transferred particle with the electricity be so considered.

491. The latest communication that I am aware of on the subject is by M. HACHETTE: its date is October 1832 ||. It is incidental to the description of the decomposition of water by the magneto-electric currents (346.). One of the results of the experiment is, that "it is not necessary, as has been supposed, that for the chemical decomposition of water, the action of the two electricities, positive and negative, should be simultaneous."

492. It is more than probable that many other views of electro-chemical decomposition may have been published, and perhaps amongst them some which, differing from those above, might, even in my own opinion, were I acquainted with them, obviate the necessity for the publication of my views. If such be the case, I have to regret my ignorance of them, and apologize to the authors.

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493. That electro-chemical decomposition does not depend upon any direct attraction and repulsion of the poles (meaning thereby the metallic terminations either of the voltaic battery, or ordinary electrical machine arrangements (312.),) upon the elements in contact with or near to them, appeared very evident from the experiments made in air (462, 465, &c.), when the substances evolved did not collect about any poles, but, in obedience to the direction

* Annales de Chimie, tom. xxviii. p. 201. † Ibid. pp. 197, 198. ‡ Ibid. pp. 192, 199.
§ Ibid. p. 200. || Ibid. tom. li. p. 73.

of the current, were evolved, and I would say ejected, at the extremities of the decomposing substance. But notwithstanding the extreme dissimilarity in the character of air and metals, and the almost total difference existing between them as to their mode of conducting electricity, and becoming charged with it, it might perhaps still be contended, although quite hypothetically, that the bounding portions of air were now the surfaces or places of attraction, as the metals had been supposed to be before. In illustration of this and other points, I endeavoured to devise an arrangement by which I could decompose a body against a surface of water, as well as against air or metal, and succeeded in doing so unexceptionably in the following manner. As the experiment for very natural reasons requires many precautions, to be successful, and will be referred to hereafter in illustration of the views I shall venture to give, I must describe it minutely.

494. A glass basin (fig. 6.), four inches in diameter and four inches deep, had a division of mica *a*, fixed across the upper part so as to descend one inch and a half below the edge, and be perfectly water-tight at the sides: a plate of platina *b*, three inches wide, was put into the basin on one side of the division *a*, and retained there by a glass block below, so that any gas produced by it in a future stage of the experiment should not ascend beyond the mica, and cause currents in the liquid on that side. A strong solution of sulphate of magnesia was carefully poured without splashing into the basin, until it rose a little above the lower edge of the mica division *a*, great care being taken that the glass or mica on the unoccupied or *c* side of the division in the figure, should not be moistened by agitation of the solution above the level to which it rose. A thin piece of clean cork, well wetted in distilled water, was then carefully and lightly placed on the solution at the *c* side, and distilled water poured gently on to it until a stratum the eighth of an inch in thickness appeared over the sulphate of magnesia; all was then left for a few minutes, that any solution adhering to the cork might sink away from it, or be removed by the water on which it now floated; and then more distilled water was added in a similar manner, until it reached nearly to the top of the glass. In this way solution of the sulphate occupied the lower part of the glass, and also the upper on the right hand side of the mica; but on the left hand side of the division a stratum of water from *c* to *d*, one inch and a half in depth, reposed upon it,

the two presenting, when looked through horizontally, a very definite plane of contact. A second platina pole *e*, was arranged so as to be just under the surface of the water, in a position nearly horizontal, a little inclination being given to it, that gas evolved during decomposition might escape: the part immersed was three inches and a half long by one inch wide, and about seven eighths of an inch of water intervened between it and the solution of sulphate of magnesia.

495. The latter pole *e* was now connected with the negative end of a voltaic battery, of forty pairs of plates four inches square, whilst the former pole *b* was connected with the positive end. There was action and gas evolved at both poles; but from the intervention of the pure water, the decomposition was very feeble compared to what the battery would have effected in a uniform solution. After a little while (less than a minute,) magnesia also appeared at the negative side: *it did not make its appearance at the negative pole*, but in the water, at the plane where the solution and the water met; and on looking at it horizontally, it could be there perceived lying in the water upon the solution, not rising more than the fourth of an inch above the latter, whilst the water between it and the negative pole was perfectly clear. On continuing the action, the bubbles of hydrogen rising upwards from the negative pole impressed a circulatory movement on the stratum of water, upwards in the middle, and downwards at the side, which gradually gave an ascending form to the cloud of magnesia in the part just under the pole, having an appearance as if it were there attracted to it; but this was altogether an effect of the currents, and did not occur until long after the phenomena required were satisfactorily ascertained.

496. After a little while the voltaic communication was broken, and the platina poles removed with as little agitation as possible from the water and solution, for the purpose of examining the liquid adhering to them. The pole *e*, when touched by turmeric paper, gave no traces of alkali, nor could anything but pure water be found upon it. The pole *b*, though drawn through a much greater depth and quantity of fluid, was found so acid as to give abundant evidence to litmus paper, the tongue, and other tests. Hence there had been no interference of alkaline salts in any way, undergoing first decomposition, and then causing the separation of the magnesia at a distance from the pole by mere chemical agencies.

This experiment was repeated again and again, and always successfully.

497. As, therefore, the substances evolved in cases of electro-chemical decomposition may be made to appear against air (465. 469.),—which, according to common language, is not a conductor, nor is decomposed; or against water (495.), which is a conductor, and can be decomposed,—as well as against the metal poles, which are excellent conductors, but undecomposable, there appears but little reason to consider the phenomena generally, as due to the *attraction* or attractive powers of the latter, when used in the ordinary way, since similar attractions can hardly be imagined in the former instances.

498. It may be said that the surfaces of air or of water in these cases become the poles, and exert attractive powers; but what proof is there of that, except the fact that the matters evolved collect there, which is the point to be explained, and cannot be justly quoted as its own explanation? Or it may be said, that any section of the humid conductor, as that in the present case, where the solution and the water meet, may be considered as representing the pole. But such does not appear to me to be the view of those who have written on the subject, certainly not of some of them, and is inconsistent with the supposed laws which they have assumed, as governing the diminution of power at increased distances from the poles.

499. Grotthuss, for instance, describes the poles as centres of attractive and repulsive forces (481), these forces varying inversely as the squares of the distances, and says, therefore, that a particle placed anywhere between the poles will be acted upon by a constant force. But the compound force, resulting from such a combination as he supposes, would be anything but a constant force; it would evidently be a force greatest at the poles, and diminishing to the middle distance. Grotthuss is right, however, *in the fact*, according to my experiments (502. 505.), that the particles are acted upon by equal force everywhere in the circuit, when the conditions of the experiment are the simplest possible; but the fact is against his theory, and is also, I think, against all theories that place the decomposing effect in the attractive power of the poles.

500. Sir Humphry Davy, who also speaks of the *diminution* of power with increase of distance from the poles * (483.), supposes, that when both poles are acting on substances to decompose them, still the power of decomposition

* Philosophical Transactions, 1807, p. 42.

diminishes to the middle distance. In this statement of fact he is opposed to Grotthuss, and quotes an experiment in which sulphate of potassa, placed at different distances from the poles in a humid conductor of constant length, decomposed when near the pole, but not when at a distance. Such a consequence would necessarily result theoretically from considering the poles as centres of attraction and repulsion; but I have not found the statement borne out by other experiments (505.); and in the one quoted by him the effect was doubtless due to some of the many interfering causes of variation which attend such investigations.

501. A glass vessel had a platina plate fixed perpendicularly across it, so as to divide it into two cells: a head of mica was fixed over it, so as to collect the gas it might evolve during experiments; then each cell, and the space beneath the mica, was filled with dilute sulphuric acid. Two poles were provided, consisting each of a platina wire terminated by a plate of the same metal; each was fixed into a tube passing through its upper end by an air-tight joint, that it might be moveable, and yet that the gas evolved at it might be collected. The tubes were filled with the acid, and one immersed in each cell. Each platina pole was equal in surface to one side of the dividing plate in the middle glass vessel, and the whole might be considered as an arrangement between the poles of the battery of a humid decomposable conductor divided in the middle by the interposed platina diaphragm. It was easy, when required, to draw one of the poles further up the tube, and then the platina diaphragm was no longer in the middle of the humid conductor. But whether it were thus arranged at the middle, or towards one side, it always evolved a quantity of oxygen and hydrogen equal to that evolved by both the extreme plates*.

502. If the wires of a galvanometer be terminated by plates, and these be immersed in dilute acid, contained in a regularly formed rectangular glass trough, connected at each end with a voltaic battery by poles equal to the section of the fluid, a part of the electricity will pass through the instrument and cause a certain deflection. And if the plates are always retained at the same distance from each other and from the sides of the trough, are always parallel to each

* There are certain precautions, in this and such experiments, which can only be understood and guarded against by a knowledge of the phenomena to be described in the first part of the Sixth Series of these Researches.

other, and uniformly placed relative to the fluid, then, whether the galvanometer plates are immersed near the middle of the decomposing solution, or near one end, still the instrument will indicate the same deflection, and consequently the same electric influence.

503. It is very evident that when the width of the decomposing conductor varies, as is always the case when mere wires or plates, as poles, are dipped into or are surrounded by solution, no constant expression can be given as to the action upon a single particle placed in the course of the current, nor any conclusion of use relative to the supposed attractive or repulsive force of the poles be drawn. The force will vary as the distance from the pole varies; as the particle is directly between the poles, or more or less on one side; and even as it is nearer to or further from the sides of the containing vessels, or as the shape of the vessel itself varies; and, in fact, by making variations in the form of the arrangement, the force upon any single particle may be made to increase, or diminish, or remain constant, whilst the distance between the particle and the pole shall remain the same; or the force may be made to increase, or diminish, or remain constant, either as the distance increases or as it diminishes.

504. From numerous experiments, I am led to believe the following general expression to be correct; but I purpose examining it much further, and would therefore wish not to be considered at present as pledged to its accuracy. The sum of chemical decomposition is constant for any section taken across a decomposing conductor, uniform in its nature, at whatever distance the poles may be from each other or from the section; or however that section may intersect the currents, whether directly across them, or so oblique as to reach almost from pole to pole, or whether it be plane, or curved, or irregular in the utmost degree; provided the current of electricity be retained constant in quantity (377.), and that the section include all portions of the current through the decomposing conductor.

505. I have reason to believe that the statement might be made still more general, and expressed thus: That for a constant quantity of electricity, whatever the decomposing conductor may be, whether water, saline solutions, acids, fused bodies, &c., the amount of electro-chemical action is also a constant quantity, i. e. would always be equivalent to a standard chemical effect founded

upon ordinary chemical affinity. I have this investigation in hand, with several others, and shall be prepared to give it in the next series but one of these Researches.

506. Many other arguments might be adduced against the hypotheses of the attraction of the poles being the cause of electro-chemical decomposition; but I would rather pass on to the view I have thought more consistent with facts, with this single remark; that if decomposition by the voltaic battery depended upon the attraction of the poles, or the parts about them, being stronger than the mutual attraction of the particles separated, it would follow that the weakest electrical attraction was stronger than, if not the strongest yet, very strong chemical attraction, namely, such as exists between oxygen and hydrogen, potassium and oxygen, chlorine and sodium, acid and alkali, &c., a consequence which, although perhaps not impossible, seems in the present state of the subject very unlikely.

507. The view which M. DE LA RIVE has taken (489.), and also MM. RIFFAULT and CHOMPRÉ (485), of the manner in which electro-chemical decomposition is effected, is very different to that already considered, and is not affected by either arguments or facts against the latter. Considering it as stated by the former philosopher, it appears to me to be incompetent to account for the experiments of decomposition against surfaces of air (462. 469.) and water (495.), which I have described; for if the physical differences between metals and humid conductors, which M. DE LA RIVE supposes to account for the transmission of the compound of matter and electricity in the latter, and the transmission of the electricity only with the rejection of the matter in the former, be allowed for a moment, still the relation of air to metal is, electrically considered, so small, that instead of the former replacing the latter (462.), an effect the very reverse might have been expected. Or if even that were allowed, the experiment with water (495.), at once sets the matter at rest, the decomposing pole being now of a substance which is admitted as competent to transmit the compound of electricity and matter.

508. With regard to the views of MM. RIFFAULT and CHOMPRÉ (485.), the occurrence of deposition in the course of the current is so contrary to the well known effects obtained in the forms of experiment adopted up to this time, that it must be proved before the hypothesis depending on it need be considered.

509. The consideration of the various theories of electro-chemical decomposition, whilst it has made me diffident, has also given me confidence to add another to the number; for it is because the one I have to propose appears, after the most attentive consideration, to explain and agree with the immense collection of facts belonging to this branch of science, and to remain uncontradicted by, or unopposed to, any of them, that I have been encouraged to give it.

510. Electro-chemical decomposition is well known to depend essentially upon the *current* of electricity. I have shown that in certain cases (375.) the decomposition is proportionate to the quantity of electricity passing, whatever may be its intensity or its source, and that the same is probably true for all cases (377.), even when the utmost generality is taken on the one hand, and great precision of expression on the other.

511. In speaking of the current, I find myself obliged to be still more particular than on a former occasion (283.), in consequence of the variety of views taken by philosophers, all agreeing in the effect of the current itself. Some philosophers, with FRANKLIN, assume but one electric fluid; and such must agree together in the general uniformity and character of the electric current. Others assume two electric fluids; and here singular differences have arisen.

512. MM. RIFFAULT and CHOMPRÉ, for instance, consider the positive and negative currents each as causing decomposition, and state that the positive current is *more powerful* than the negative current*, the nitrate of soda being, under similar circumstances, decomposed by the former, but not by the latter.

513. M. HACHETTE states† that "it is not necessary, as has been believed, that the action of the two electricities, positive and negative, should be simultaneous for the decomposition of water." The passage implying, if I have caught the meaning aright, that one electricity can be obtained, and can be applied in effecting decompositions, independent of the other.

514. The view of M. DE LA RIVE to a certain extent agrees with that of M. HACHETTE, for he considers that the two electricities decompose separate portions of water (490.)‡. In one passage he speaks of the two electricities as two influences, wishing perhaps to avoid offering a decided opinion upon the independent existence of electric fluids; but as these influences are consi-

* Annales de Chimie, 1807, tom. lxiii. p. 84.

† Ibid. 1832, tom. li. p. 73.

‡ Ibid. 1825, tom. xxviii. pp. 197, 201.

dered as combining with the elements set free as by a species of chemical affinity, and for the time entirely masking their character, great vagueness of idea is thus introduced, inasmuch as such species of combination can only be conceived to take place between things having independent existence. The two elementary electric currents, moving in opposite directions, from pole to pole, constitute the ordinary *voltaic current*.

515. M. Grotthuss is inclined to believe that the elements of water, when about to separate at the poles, combine with the electricities, and so become gases. M. de la Rive's view is the exact reverse of this: whilst passing through the fluid, they are, according to him, compounds with the electricities; when evolved at the poles, they are de-electrified.

516. I have sought amongst the various experiments quoted in support of these views, or connected with electro-chemical decompositions or electric currents, for any which might be considered as sustaining the theory of two electricities rather than that of one, but have not been able to perceive a single fact which could be brought forward for such a purpose: or, admitting the hypothesis of two electricities, much less have I been able to perceive the slightest grounds for believing that one electricity in a current can be more powerful than the other, or that it can be present without the other, or that one can be varied, or in the slightest degree affected, without a corresponding variation in the other. If, upon the supposition of two electricities, a current of one can be obtained without the other, or the current of one be exalted or diminished more than the other, we might surely expect some variation either of the chemical or magnetical effects, or of both; but no such variations have been observed. If a current be so directed that it may act chemically in one part of its course, and magnetically in another, the two actions are always found to take place together. A current has not, to my knowledge, been produced which could act chemically and not magnetically, nor any which can act on the magnet, and not *at the same time* chemically*.

517. *Judging from facts only*, there is not as yet the slightest reason for considering the influence which is present in what we call the electric current,—whether in metals or fused bodies or humid conductors, or even in air, flame,

* Thermo-electric currents are of course no exception, because when they fail to act chemically they also fail to be currents.

and rarefied elastic media,—as a compound or complicated influence. It has never been resolved into simpler or elementary influences, and may perhaps best be conceived of as *an axis of power having contrary forces, exactly equal in amount, in contrary directions.*

518. Passing to the consideration of electro-chemical decomposition, it appears to me that the effect is produced by an *internal corpuscular action*, exerted according to the direction of the electric current, and that it is due to a force either *superadded to*, or *giving direction to the ordinary chemical affinity* of the bodies present. The decomposing body may be considered as a mass of acting particles, all those which are included in the course of the electric current contributing to the final effect; and it is because the ordinary chemical affinity is relieved, weakened, or partly neutralized by the influence of the electric current in one direction, parallel to the course of the latter, and strengthened or added to in the opposite direction, that the combining particles have a tendency to pass in opposite courses.

519. In this view the effect is considered as *essentially dependent* upon the *mutual chemical affinity* of the particles of opposite kinds. Particles *a a*, fig. 7, could not be transferred or travel from one pole N towards the other P, unless they found particles of the opposite kind *b b*, ready to pass in the contrary direction: for it is by virtue of their increased affinity for those particles, combined with their diminished affinity for such as are behind them in their course, that they are urged forward: and when any one particle *a*, fig. 8, arrives at the pole, it is excluded or set free, because the particle *b* of the opposite kind, with which it was the moment before in combination, has, under the superinducing influence of the current, a greater attraction for the particle a', which is before it in its course, than for the particle *a*, towards which its affinity has been weakened.

520. As far as regards any single compound particle, the case may be considered as analogous to one of ordinary decomposition, for in fig. 8, *a* may be conceived to be expelled from the compound *a b* by the superior attraction of a' for *b*, that superior attraction belonging to it in consequence of the relative position of a' *b* and *a* to the direction of the axis of electric power (517.) superinduced by the current. But as all the compound particles in the course of the current, except those actually in contact with the poles, act conjointly, and consist of elementary particles, which, whilst they are in one direction

expelling, are in the other being expelled, the case becomes more complicated, but not more difficult of comprehension.

521. It is not here assumed that the acting particles must be in a right line between the poles. The lines of action which may be supposed to represent the electric currents passing through a decomposing liquid, have in many experiments very irregular forms; and even in the simplest case of two wires or points immersed as poles in a drop, or larger single portion of fluid, these lines must diverge rapidly from the poles; and the direction in which the chemical affinity between particles is most powerfully modified (519. 520.) will vary with the direction of these lines, according constantly with them. But even in reference to these lines or currents, it is not supposed that the particles which mutually affect each other must of necessity be parallel to them, but only that they shall accord generally with their direction. Two particles, placed in a line perpendicular to the electric current passing in any particular place, are not supposed to have their ordinary chemical relations towards each other affected; but as the line joining them is inclined one way to the current, their mutual affinity is increased; as it is inclined in the other direction, it is diminished; and the effect is a maximum, when that line is parallel to the current.

522. That the actions, of whatever kind they may be, take place frequently in oblique directions is evident from the circumstance of those particles being included which in numerous cases are not in a line between the poles. Thus, when wires are used as poles in a glass of solution, the decompositions and recompositions occur to the right or left of the direct line between the poles, and indeed in every part to which the currents extend, as is proved by many experiments, and must therefore often occur between particles obliquely placed as respects the current itself; and when a metallic vessel containing the solution is made one pole, whilst a mere point or wire is used for the other, the decompositions and recompositions must frequently be still more oblique to the course of the currents.

523. The theory which I have ventured to put forth (almost) requires an admission, that in a compound body capable of electro-chemical decomposition the elementary particles have a mutual relation to, and influence upon each other, extending beyond those with which they are immediately combined. Thus in water, a particle of hydrogen in combination with oxygen is considered

as not altogether indifferent to other particles of oxygen, although they are combined with other particles of hydrogen; but to have an affinity or attraction towards them, which, though it does not at all approach in force, under ordinary circumstances, to that by which it is combined with its own particle, can under the electric influence, exerted in a definite direction, be made even to surpass it. This general relation of particles already in combination to other particles with which they are not combined, is sufficiently distinct in numerous results of a purely chemical character, especially in those where partial decompositions only take place, and in BERTHOLLET's experiments on the effects of quantity upon affinity; and it probably has a direct relation to, and connexion with, attraction of aggregation, both in solids and fluids. It is a remarkable circumstance, that in gases and vapours, where the attraction of aggregation ceases, there likewise the decomposing powers of electricity apparently cease, and there also the chemical action of quantity is no longer evident. It seems not unlikely, that the inability to suffer decomposition in these cases may be dependent upon the absence of that mutual attractive relation of the particles which is the cause of aggregation.

524. I hope I have now distinctly stated, although in general terms, the view I entertain of the cause of electro-chemical decomposition, as far as that cause can at present be traced and understood. I conceive the effects to arise from forces which are *internal*, relative to the matter under decomposition—and not *external*, as they might be considered, if directly dependent upon the poles. I suppose that the effects are due to a modification, by the electric current, of the chemical affinity of the particles through or by which that current is passing, giving them the power of acting more forcibly in one direction than in another, and consequently making them travel by a series of successive decompositions and recompositions in opposite directions, and finally causing their expulsion or exclusion at the boundaries of the decomposing body, in the direction of the current, and *that* in larger or smaller quantities, according as the current is more or less powerful (377.). I think, therefore, it would be more philosophical, and more directly expressive of the facts, to speak of a decomposing body, in relation to the current passing through it, rather than to the poles, as they are usually called, in contact with it; and say that whilst under decomposition, oxygen, chlorine, iodine, acids, &c., are rendered at the

negative extremity, and combustibles, metals, alkalies, bases, &c., at the positive extremity of the decomposing substance (467.). I do not believe that a substance can be transferred in the electric current beyond the point where it ceases to find particles with which it can combine; and I may refer to the experiments made in air (465.), and in water (495.), already quoted, for facts illustrating these views in the first instance; to which I will now add others.

525. In order to show the dependence of the decomposition and transfer of elements upon the chemical affinity of the substances present, experiments were made upon sulphuric acid in the following manner. Dilute sulphuric acid was prepared: its specific gravity was 1021·2. A solution of sulphate of soda was also prepared, of such strength that a measure of it contained exactly as much sulphuric acid as an equal measure of the diluted acid just referred to. A solution of pure soda, and another of pure ammonia, were likewise prepared, of such strengths that a measure of either should be exactly neutralized by a measure of the prepared sulphuric acid.

526. Four glass cups were then arranged, as in fig. 9; seventeen measures of the free sulphuric acid (525.) were put into each of the vessels *a* and *b*, and seventeen measures of the solution of sulphate of soda into each of the vessels A and B. Asbestus, which had been well washed in acid, acted upon by the voltaic pile, well washed in water, and dried by pressure, was used to connect *a* with *b* and A with B, the portions being as equal as they could be made in quantity, and cut as short as was consistent with their performing the part of effectual communications. *b* and A were connected by two platina plates or poles soldered to the extremities of one wire, and the cups *a* and B were by similar platina plates connected with a voltaic battery of forty pairs of plates four inches square, that in *a* being connected with the negative, and that in B with the positive pole. The battery, which was not powerfully charged, was retained in communication above half an hour. In this manner it was certain that the same electric current had passed through *a b* and A B, and that in each instance the same quantity and strength of acid had been submitted to its action, but in one case merely dissolved in water, and in the other dissolved and also combined with an alkali.

527. On breaking the connexion with the battery, the portions of asbestus were lifted out, and the drops hanging at the ends allowed to fall each into its

respective vessel. The acids in *a* and *b* were then first compared, for which purpose two evaporating dishes were balanced, and the acid from *a* put into one, and that from *b* into the other; but as one was a little heavier than the other, a small drop was transferred from the heavier to the lighter, and the two rendered equal in weight. Being neutralized by addition of the soda solution (525.), that from *a*, or the negative vessel, required 15 parts of the soda solution, and that from *b*, or the positive vessel, required 16·3 parts. That the sum of these is not 34 parts is principally due to the acid removed with the asbestus; but, taking the mean of 15·65 parts, it would appear that a twenty-fourth part of the acid originally in the vessel *a* had passed, through the influence of the electric current, from *a* into *b*.

528. In comparing the difference of acid in A and B, the necessary equality of weight was considered as of no consequence, because the solution was at first neutral, and would not, therefore, affect the test liquids, and all the evolved acid would be in B, and the free alkali in A. The solution in A required 3·2 measures of the prepared acid (525.) to neutralize it, and the solution in B required also 3·2 measures of the soda solution (525.) to neutralize it. As the asbestus must have removed a little acid and alkali from the glasses, these quantities are by so much too small; and therefore it would appear that about a tenth of the acid originally in the vessel A had been transferred into B during the continuance of the electric action.

529. In another similar experiment, whilst a thirty-fifth part of the acid passed from *a* to *b* in the free acid vessels, between a tenth and an eleventh passed from A to B in the combined acid vessels. Other experiments of the same kind gave similar results.

530. The variation of electro-chemical decomposition, the transfer of elements and their accumulation at the poles, according as the substance submitted to action consists of particles opposed more or less in their chemical affinity, together with the consequent influence of the latter circumstances, are sufficiently obvious in these cases, where sulphuric acid is acted upon in the *same quantity* by the *same* electric current, but in one case opposed to the comparatively weak affinity of water for it, and in the other to the stronger one of soda. In the latter case the quantity transferred is from two and a half to three times what it is in the former; and it appears therefore very evident that

the transfer is greatly dependent upon the mutual action of the particles of the decomposing bodies.

531. In some of the experiments the acid from the vessels *a* and *b* was neutralized by ammonia, then evaporated to dryness, heated to redness, and the residue examined for sulphates. In these cases more sulphate was always obtained from *a* than from *b*; showing that it had been impossible to exclude saline bases (derived from the asbestus, the glass, or perhaps impurities originally in the acid,) and that they had helped in transferring the acid into *b*. But the quantity was small, and the acid was principally transferred by relation to the water present.

532. I endeavoured to arrange certain experiments by which saline solutions should be decomposed against surfaces of water; and at first worked with the electric machine upon a piece of bibulous paper, or asbestus moistened in the solution, and in contact at its two extremities with pointed pieces of paper moistened in pure water, which served to carry the electric current to and from the solution in the middle piece. But I found numerous interfering difficulties. Thus, the water and solutions in the pieces of paper could not be prevented from mingling at the point where they touched. Again, sufficient acid could be derived from the paper connected with the discharging train, or it may be even from the air itself, under the influence of electric action, to neutralize the alkali developed at the positive extremity of the decomposing solution, and so not merely prevent its appearance, but actually transfer it on to the metal termination: and, in fact, when the paper points were not allowed to touch there, and the machine was worked until alkali was evolved at the delivering or positive end of the turmeric paper, containing the sulphate of soda solution, it was merely necessary to place the opposite receiving point of the paper connected with the discharging train, which had been moistened by distilled water, upon the browned turmeric point and press them together, when the alkaline effect immediately disappeared.

533. The experiment with sulphate of magnesia already described (495.) is a case in point, however, and shows most clearly that the sulphuric acid and magnesia contributed to each other's transfer and final evolution, exactly as the same acid and soda affected each other in the results just given (527, &c.); and that so soon as the magnesia advanced beyond the reach of the acid, and

found no other substance with which it could combine, it appeared in its proper character, and was no longer able to continue its progress towards the negative pole.

534. The theory I have ventured to put forth appears to me to explain all the prominent features of electro-chemical decomposition in a satisfactory manner.

535. In the first place it explains why, in all ordinary cases, the evolved substances appear only at the poles; for the poles are the limiting surfaces of the decomposing substance, and except at them, every particle finds other particles having a contrary tendency with which it can combine.

536. Then it explains why, in numerous cases, the elements or evolved substances are not *retained* by the poles; and this is no small difficulty in those theories which refer the decomposing effect directly to the attractive power of the poles. If a piece of platina have sufficient power given to it by any means to attract a particle of hydrogen from the particle of oxygen with which it was the instant before combined, there seems no sufficient reason, nor any fact, except those to be explained, which show why it should not, according to analogy with all ordinary attractive forces, as those of gravitation, the magnet, cohesion, chemical affinity, &c., *retain* that particle which it had just before taken from a distance and from previous combination. Yet it does not do so, but allows it to escape freely. Nor does this depend upon its assuming the gaseous state, for acids and alkalies, &c., are left equally at liberty to diffuse themselves through the fluid surrounding the pole, and show no particular tendency to combine with or cleave to the latter. And though there are plenty of cases where combination with the pole does take place, they do not at all explain the instances of non-combination, and do not therefore in their particular action reveal the general principle of decomposition.

537. But in the theory that I have just given, the effect appears to be a natural consequence of the action: the evolved substances are expelled from the decomposing mass (518. 519.), not *drawn out by an attraction* which ceases to act on one particle without any assignable reason, while it continues to act on another of the same kind: and whether the poles be metal, water, or air, still the substances are evolved, and sometimes are set free, or sometimes unite to the matter of the poles, according to the chemical nature of the latter, i. e. the chemical relation of their particles to those which are leaving the substance under operation.

538. The theory accounts for the transfer of elements in a manner which seems to me at present to leave nothing unexplained; and it was, indeed, the phenomena of transfer in the numerous cases of decomposition of bodies rendered fluid by heat (380. 402.), which, in conjunction with the experiments in air, led to its construction. Such cases as the former where binary compounds of easy decomposability are acted upon, are perhaps the best to illustrate the theory.

539. Chloride of lead, for instance, fused in a bent tube (400.), and decomposed by platina wires, evolves lead, passing to what is usually called the negative pole, and chlorine, which being evolved at the positive pole, is in part set free, and in part combines with the platina. The chloride formed, being soluble in the chloride of lead, is subject to decomposition, and the platina itself is gradually transferred across the decomposing matter, and found with the lead at the negative pole.

540. Iodide of lead evolves abundance of lead at the negative pole, and abundance of iodine at the positive pole.

541. Chloride of silver furnishes a beautiful instance, especially when decomposed by silver wire poles. Upon fusing a portion of it on a piece of glass, and bringing the poles into contact with it, there is abundance of silver evolved at the negative pole, and an equal abundance absorbed at the positive pole, for no chlorine is set free; and by careful management, the negative wire may be withdrawn from the fused globule as the silver is reduced there, the latter serving as the continuation of the pole, until a wire or thread of revived silver, five or six inches in length, is produced; at the same time the silver at the positive pole is as rapidly dissolved by the chlorine, which seizes upon it, so that the wire has to be continually advanced as it is melted away. The whole experiment includes the action of only two elements, silver and chlorine, and illustrates in a beautiful manner their progress in opposite directions, parallel to the electric current, which is for the time giving a uniform general direction to their mutual affinities (524.).

542. According to my theory, an element or a substance not decomposable under the circumstances of the experiment, (as, for instance, a dilute acid or alkali,) should not be transferred, or pass from pole to pole, unless it be in chemical relation to some other element or substance tending to pass in the opposite direction, for the effect is considered as essentially due to the mutual

relation of such particles. But the theories attributing the determination of the elements to the attractions and repulsions of the poles require no such condition, i. e. there is no reason apparent why the attraction of the positive pole, and the repulsion of the negative pole, upon a particle of free acid, placed in water between them, should not (with equal currents of electricity) be as strong as if that particle were previously combined with alkali; but, on the contrary, as they have not a powerful chemical affinity to overcome, there is every reason to suppose they would be stronger, and would sooner bring the acid to rest at the positive pole*. Yet such is not the case, as has been shown by the experiments on free and combined acid (526. 528.).

543. Neither does M. DE LA RIVE's theory, as I understand it, require that the particles should be in combination: it does not even admit, where there are two sets of particles capable of combining with and passing by each other, that they do combine, but supposes that they travel as separate compounds of matter and electricity. Yet in fact, the free substance *cannot* travel, the combined one *can*.

544. It is very difficult to find cases amongst solutions or fluids which shall illustrate this point, because of the difficulty of finding two fluids which shall conduct, shall not mingle, and in which an element evolved from one shall not find a combinable element in the other. Solutions of acids or alkalies will not answer, because they exist by virtue of an attraction; and increasing the solubility of a body in one direction, and diminishing it in the opposite, is just as good a reason for transfer, as modifying the affinity between the acid and alkali themselves. Nevertheless the case of sulphate of magnesia is in point (494. 495.), and shows that one element or principle only has no power of transference or of passing towards either pole.

545. Many of the metals, however, in their solid state, offer very fair instances of the kind required. Thus, if a plate of platina be used as the positive pole in a solution of sulphuric acid, oxygen will pass towards it, and so will acid; but these are not substances having such chemical relation to the platina as, even under the favourable condition superinduced by the current (518. 524.), to combine with it; the platina therefore remains where it was first placed, and has

* Even Sir HUMPHRY DAVY considered the attraction of the pole as being communicated from one particle to another of the *same* kind (483.).

no tendency to pass towards the negative pole. But if a plate of iron, zinc or copper, be substituted for the platina, then the oxygen and acid can combine with these, and the metal immediately begins to travel as an oxide, to the opposite pole, and is finally deposited there. Or if, retaining the platina pole, a fused chloride, as of lead, zinc, silver, &c., be substituted for the sulphuric acid, then, as the platina finds an element it can combine with, it enters into union, acts as other elements do in cases of voltaic decomposition, is rapidly transferred across the melted matter, and expelled at the negative pole.

546. I can see but little reason in the theories referring the electro-chemical decomposition to the attractions and repulsions of the poles, and I can perceive none in M. DE LA RIVE'S theory, why the metal of the positive pole should not be transferred across the intervening conductor, and deposited at the negative pole, even when it cannot act chemically upon the element of the fluid surrounding it. It cannot be referred to the attraction of cohesion preventing such an effect; for if the pole be made of the lightest spongy platina, the effect is the same. Or if gold precipitated by sulphate of iron be diffused through the solution, still accumulation of it at the negative pole will not take place; and yet in it the attraction of cohesion is almost perfectly overcome, the particles are so small as to remain for hours in suspension, and are perfectly free to move by the slightest impulse towards either pole; and *if in relation* by chemical affinity to any substance present, are powerfully determined to the negative pole *.

547. In support of these arguments, it may be observed, that as yet no determination of a substance to a pole, or tendency of obedience to the electric current, has been observed (that I am aware of,) in cases of mere mixture; i. e. a substance diffused through a fluid, but having no sensible chemical affinity with it, or with substances that may be evolved from it during the action,

* In making this experiment, care must be taken that no substance be present that can act chemically on the gold. Although I used the metal very carefully washed, and diffused through dilute sulphuric acid, yet in the first instance I obtained gold at the negative pole, and the effect was repeated when the platina poles were changed. But on examining the clear liquor in the cell, after subsidence of the metallic gold, I found a little of that metal in solution, and a little chlorine was also present. I therefore well washed the gold which had thus been subjected to voltaic action, diffused it through other pure dilute sulphuric acid, and then found that on subjecting it to the action of the poles, not the slightest tendency to the negative pole could be perceived.

does not in any case seem to be affected by the electric current. Pulverised charcoal was diffused through dilute sulphuric acid, and subjected with the solution to the action of a voltaic battery, terminated by platina poles; but not the slightest tendency of the charcoal to the negative pole could be observed. Sublimed sulphur was diffused through similar acid, and submitted to the same action, a silver plate being used as the negative pole; but the sulphur had no tendency to pass to that pole, the silver was not tarnished, nor did any sulphuretted hydrogen appear. The case of magnesia and water (495. 533.), with those of comminuted metals in certain solutions (546.), are also of this kind; and, in fact, substances which have the instant before been powerfully determined towards the pole, as magnesia from sulphate of magnesia, become entirely indifferent to it the moment they assume their independent state, and pass away, diffusing themselves in the surrounding fluid.

548. There are, it is true, many instances of insoluble bodies being acted upon, as glass, sulphate of baryta, marble, slate, basalt, &c., but they form no exception; for the substances they give up are in direct and strong relation as to chemical affinity with those which they find in the surrounding solution, so that these decompositions enter into the class of ordinary effects.

549. It may be expressed as a general consequence, that the more directly bodies are opposed to each other in chemical affinity, the more *ready* is their separation from each other in cases of electro-chemical decomposition, i. e. provided other circumstances, as insolubility, deficient conducting power, proportions, &c., do not interfere. This is well known to be the case with water and saline solutions; and I have found it to be equally true with *dry* chlorides, iodides, salts, &c., rendered subject to electro-chemical decomposition by fusion (402.). So that in applying the voltaic battery for the purpose of decomposing bodies not yet resolved into forms of matter simpler than their own, it must be remembered, that success may depend not upon the weakness, or failure upon the strength, of the affinity by which the elements sought for are held together, but contrariwise; and then modes of application may be devised by which, in *association* with ordinary chemical powers, and the assistance of fusion (394. 417.), we may be able to penetrate much further than at present into the constitution of our chemical elements.

550. Some of the most beautiful and surprising cases of electro-chemical

decomposition and transfer which Sir HUMPHRY DAVY described in his celebrated paper*, were those in which acids were passed through alkalies, and alkalies or earths through acids†; and the way in which substances having the most powerful attractions for each other were thus prevented from combining, or, as it is said, had their natural affinity destroyed or suspended throughout the whole of the circuit, excited the utmost astonishment. But if I be right in the view I have taken of the effects, it will appear, that that which made the *wonder*, is in fact the *essential condition* of transfer and decomposition, and that the more alkali there is in the course of an acid, the more will the transfer of that acid be facilitated from pole to pole; and perhaps a better illustration of the difference between the theory I have ventured, and those previously existing, cannot be offered than the views they respectively give of such facts as these.

551. The instances in which sulphuric acid could not be passed through baryta, or baryta through sulphuric acid‡, because of the precipitation of sulphate of baryta, enter within the pale of the law already described (380. 412.), by which liquidity is so generally required. In assuming the solid state of sulphate of baryta, they became virtually non-conductors to electricity of so low a tension as that of the voltaic battery, and the power of the latter over them was almost infinitely diminished.

552. The theory I have advanced accords in a most satisfactory manner with the fact of an element or substance finding its place of rest, or rather of evolution, sometimes at one pole and sometimes at the other. Sulphur illustrates this effect very well. When sulphuric acid is decomposed by the pile, sulphur is evolved at the negative pole; but when sulphuret of silver is decomposed in a similar way (436.), then the sulphur appears at the positive pole; and if a hot platina pole be used so as to vaporize the sulphur evolved in the latter case, then the relation of that pole to the sulphur is exactly the same as the relation of the same pole to oxygen upon its immersion in water. In both cases the element evolved is liberated at the pole, but not retained by it; but by virtue of its elastic, uncombinable, and immiscible condition passes away into the surrounding medium. The sulphur is evidently determined in these opposite directions by its opposite chemical relations to oxygen and silver; and it is to such relations generally that I have referred all electro-chemical phenomena.

* Philosophical Transactions, 1807, p. 1. † Ibid. p. 24, &c. ‡ Ibid. p. 25, &c.

Where they do not exist, no electro-chemical action can take place. Where they are strongest, it is most powerful; where they are reversed, the direction of transfer of the substance is reversed with them.

553. *Water* may be considered as one of those substances which can be made to pass to *either* pole. When the poles are immersed in dilute sulphuric acid (527.), acid passes towards the positive pole, and water towards the negative pole; but when they are immersed in dilute alkali, the alkali passes towards the negative pole, and water towards the positive pole.

554. Nitrogen is another substance which is considered as determinable to either pole; but in consequence of the numerous compounds which it forms, some of which pass to one pole and some to the other, I have not always found it easy to determine the true circumstances of its appearance. A pure strong solution of ammonia is so bad a conductor of electricity that it is scarcely more decomposable than pure water; but if sulphate of ammonia be dissolved in it, then decomposition takes place very well, nitrogen almost pure, and in some cases quite, is evolved at the positive pole, and hydrogen at the negative pole.

555. On the other hand, if a strong solution of nitrate of ammonia be decomposed, oxygen appears at the positive pole, and hydrogen, with sometimes nitrogen, at the negative pole. If fused nitrate of ammonia be employed, hydrogen appears at the negative pole, mingled with a little nitrogen. Strong nitric acid yields plenty of oxygen at the positive pole, but no gas (only nitrous acid,) at the negative pole. Weak nitric acid yields the oxygen and hydrogen of the water present, the acid apparently remaining unchanged. Strong nitric acid, with nitrate of ammonia dissolved in it, yields a gas at the negative pole, of which the greater part is hydrogen, but apparently a little nitrogen is present. I believe, that in some of these cases a little nitrogen appeared at the negative pole. I suspect, however, that in all these, and in all former cases, the appearance of the nitrogen at the positive or negative pole is entirely a secondary effect, and not an immediate consequence of the decomposing power of the electric current.

556. A few observations on what are called the *poles* of the voltaic battery now seem necessary. The poles are merely the surfaces or doors by which the electricity enters into or passes out of the decomposing substance. They limit the extent of that substance in the course of the electric current, being its

termination in that direction: hence the elements evolved pass so far and no further.

557. Metals make admirable poles, in consequence of their high conducting power, their immiscibility with the substances generally acted upon, their solid form, and the opportunity afforded of selecting some upon which ordinary substances exert no chemical action.

558. Water makes a pole of difficult application, except in a few cases (494.), because of its small conducting power, its miscibility with most of the substances acted upon, and its general relation to them in respect to chemical affinity. It consists of elements, which in their electrical and chemical relations are directly and powerfully opposed, yet combining to produce a body more neutral in its character than any other. So that there are but few substances which do not come into relation, by chemical affinity, with water or one of its elements; and therefore either the water or its elements are transferred and assist in transferring the infinite variety of bodies which, in association with it, can be placed in the course of the electric current. Hence the reason why it so rarely happens that the evolved substances rest at the first surface of the water, and why it therefore does not exhibit the ordinary action of a pole.

559. Air, however, and some gases are free from the latter objection, and may be used as poles in many cases (461, &c.); but, in consequence of the extremely low degree of conducting power belonging to them, they cannot be employed with the voltaic apparatus. This limits their use; for the voltaic apparatus is the only one as yet discovered which supplies sufficient quantity of electricity (371.376.) to effect electro-chemical decomposition with facility.

560. Where the poles are liable to the chemical action of the substances evolved, either simply in consequence of their natural relation to them, or of that relation aided by the influence of the current (518.), then they suffer corrosion, and the parts dissolved are subject to transference, in the same manner as particles of the original decomposing body. An immense series of phenomena of this kind might be quoted in support of the view I have taken of the cause of electro-chemical decomposition, and transfer and evolution of the elements. Thus platina, as the positive and negative poles in a solution of sulphate of soda, has no affinity or attraction for the oxygen, hydrogen, acid, or alkali evolved, and refuses to combine with or retain them. Zinc can com-

bine with the oxygen and acid; at the positive pole it does combine, and immediately begins to travel as oxide towards the negative pole. Charcoal, which cannot combine with the metals, if made the negative pole in a metallic solution, refuses to unite to the bodies which are ejected from the solution upon its surface; but if made the positive pole in a dilute solution of sulphuric acid, it is capable of combining with the oxygen evolved there, and consequently unites with it, producing both carbonic acid and carbonic oxide in abundance.

561. A great advantage is frequently supplied, by the opportunity afforded amongst the metals of selecting a substance for the pole which shall or shall not be acted upon by the elements to be evolved. The consequent use of platina is notorious. In the decomposition of sulphuret of silver and other sulphurets, a positive silver pole is superior to a platina one, because in the former case the sulphur evolved there is combined with the silver, and the decomposition of the original sulphuret rendered evident; whereas in the latter case it is dissipated, and the assurance of its separation at the pole not easily obtained.

562. The effects which take place when a succession of conducting decomposable and undecomposable substances are placed in the electric circuit, as, for instance, of wires and solutions, or of air and solutions (465. 469.), are explained in the simplest possible manner by the view I have given. In consequence of the reaction of the constituents of each portion of decomposable matter, affected as they are by the supervention of the electric current (524.), portions of the proximate or ultimate elements proceed in the direction of the current as far as they find matter of a contrary kind capable of effecting their transfer, and being equally affected by them; and where they cease to find such matter, they are evolved in their free state, i. e. upon the surfaces of metal or air bounding the extent of decomposable matter in the direction of the currents.

563. Having thus given my theory of the mode in which electro-chemical decomposition is effected, I will refrain for the present from entering upon the numerous general considerations which it suggests, wishing first to submit it to the test of publication and discussion.

Royal Institution,
June 1833.

XXIX. *The Anatomy and Physiology of the Liver.* By Francis Kiernan, *Esq., Member of the Royal College of Surgeons, late Teacher of Anatomy. Communicated by* J. H. Green, *Esq., F.R.S.*

Received June 20,—Read June 20, 1833.

THE small bodies of which the liver is composed, and which have been known to anatomists, since the time of Malpighi, by the various names of acini, lobules, corpuscula, glandular grains and granulations, were discovered by Wepfer in the liver of the pig about two years before the appearance of Malpighi's celebrated work De Viscerum Structurâ Exercitatio Anatomica. Wepfer contented himself with indicating the existence of the lobules in one animal*. Malpighi, unacquainted, as it would appear, with Wepfer's discovery, commenced his researches on the lower animals, and pursuing them through every class, ascertained that a similar arrangement of structure existed in all. In shell-fish, he says†, the lobules resemble bunches of grapes, and are composed of small conglobate bodies, like grape-stones, which are connected together by means of central vessels. He observed a similar conformation in lizards, in which animals the edges and interstices of the lobules are denoted by dark points. After describing the liver of the ferret, mouse, squirrel and ox, he informs us that the human liver also is composed of lobules, which represent a congeries of clusters, and may be rendered apparent by boil-

* I have not been able to find Wepfer's Work: his words, as quoted by Malpighi, Opera Posthuma, p. 32, Londini 1697, and by Portal, Histoire de l'Anatomie, tom. iii. p. 243, are—"Expendas euge hepar suillum coctum: invenies detractâ extimâ membranâ, totam et vastem hanc molem, quasi ex innumeris glandulis combinatam. In aliis jecoribus, fateor, nondum observavi: sed fracto suillo bene cocto vidi glandulas quadrangulares, aliterque ratione figuræ affectas. Perlectis Clarissimi Nicolai Stenonis observationibus cogitavi, quia et hepar quasi conglomerata est, an fortè hepatis officium foret lympham suo modo præparare ad usus corporis utiles, eamque juxta bilem secernere?"—De Dubiis Anatomicis, Epistola ad Jacob. Hen. Paulum. Norimberg 1664.

† De Hepate, cap. 2.

ing the organ and taking off its external coat. The lobules, he says, are appended to the extremities of the vessels contained in Glisson's capsule, and are invested in membranous tunics connected together by transverse bands. They vary in form in different animals: in fishes they resemble the leaf of the trefoil; in some animals they are pisiform; in the cat they have six or more sides; and they assume the hexagonal form in the human liver. Biliary calculi found in the liver were thought by MALPIGHI to be petrified lobules. Respecting the structure of the lobules, MALPIGHI informs us, that the glandular acini of which these bodies are composed have six or more sides; that they are connected by their vessels and bound together by proper membranes, the interstices between them being very apparent in the lower animals and in fishes, but obscure in the higher animals. MALPIGHI, having thus convinced himself of the existence of glandular acini in the liver, similar to those already known in the pancreas and thymus, classed this organ among the conglomerate glands*; but as he gave no representations by plates of the important discoveries he made, some difficulty has been experienced in understanding his descriptions †. Thus, he speaks of two kinds of bodies, of lobules and of acini: anatomists ‡, however, having used these terms indifferently to designate the same objects, have not understood them in the sense in which they were employed by MALPIGHI. MALPIGHI's discoveries in the anatomy of the liver are almost confined to the ascertaining its lobulated structure: he was unacquainted with the form of the lobules, with their peculiar arrangement around the hepatic veins, and with the manner in which the vessels are distributed; nor has much light been thrown on these points by the researches of more modern anatomists, although very considerable additions have been lately made to our knowledge of the ultimate

* De Hepate, cap. 3.

† The lobules and acini, as described by MALPIGHI, have been delineated by MASCAGNI, Prodromo della grande Anatomia, tab. vi. figg. 13, 14, 17. They have been also represented by BIDLOO, Anatomia Corporis Humani, tab. 38. fig. 1. The same figure will be found in COWPER's Anatomy of Humane Bodies.

‡ "On peut donner le nom de *lobules* (*acini*) aux petits amas de substance médullaire et de substance corticale réunies."—MECKEL, Anatomie Générale Descriptive et Pathologique, tom. iii. p. 453.

"M. FERREIN a trouvé dans chaque grain ou lobule du foye deux substances différentes."—Mémoires de l'Académie Royale des Sciences, Histoire. 1733. SŒMMERRING also, in speaking of the lobules, calls them *acini*.

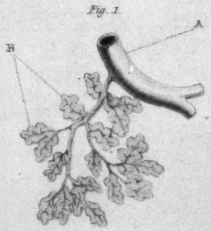
Fig. 1
A
B

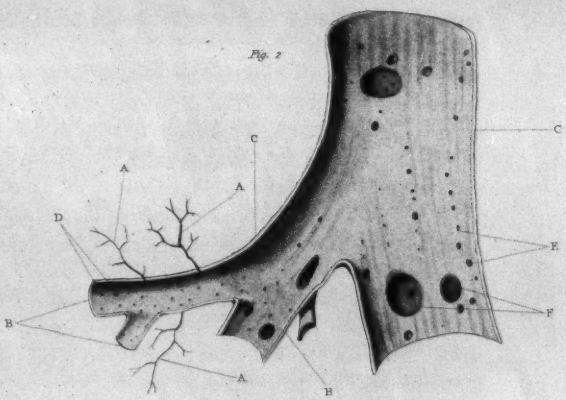
Fig. 2
C
A
A
D
E
F
B
A
B

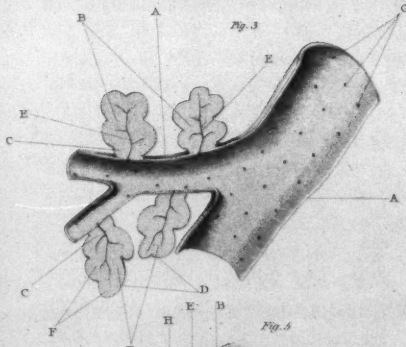
Fig. 3
B
A
G
E
E
C
A
C
D
F

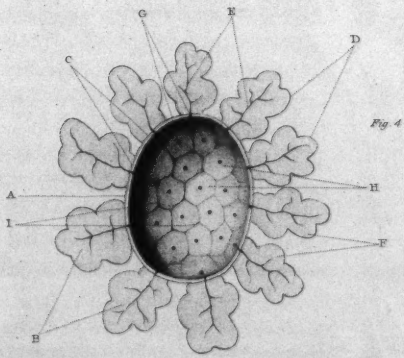
Fig. 4
G
E
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H
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F
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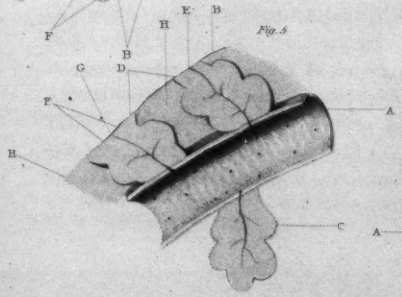


Fig. 5
E
B
H
B
G
D
F
A
H
C

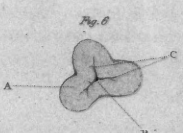


Fig. 6
C
A
B

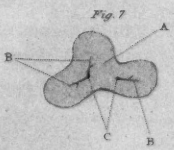


Fig. 7
A
B
C
B

structure of the liver and of other glands by the important discoveries of Müller*.

The following pages contain an account of my own investigations of the structure of this organ. The description I propose to give will embrace, 1st, that of the lobules, the manner of their arrangement, their connexions with each other and with the vessels; 2ndly, the surfaces of the liver and the distribution of the vessels; and 3rdly, the structure of the lobules.

Of the Lobules.—The hepatic veins with the lobules present a tolerably accurate resemblance to the trunk, branches and leaves of a tree. (Plate XX. fig. 1.) The lobules may be compared to the leaves. The substance of the lobules is arranged around the minute branches of the veins in a manner which may be compared to the disposition of the parenchyma of a leaf around its fibres. The vessels in which the minute veins terminate may be compared to the branches of the tree, and these vessels by their junction form the trunks. The hepatic veins may be divided into two classes; into those veins contained in the lobules, and those contained in canals formed by the lobules. The first class is composed of the intralobular branches, one of which occupies the centre of each lobule, and receives the blood from a plexus formed in the lobule by the portal vein. (Plate XX. fig. 2, *a*.) The second class of hepatic veins is composed of all those vessels contained in canals formed by the lobules. Numerous small branches, as well as the large trunks which terminate in the inferior cava, are included in this class; they all resemble each other in being contained in canals, and they differ from the vessels of the first class which are contained in the lobules. The intralobular veins terminate in some of these vessels, and not in others; these vessels therefore admit of being divided into two sets; 1st, those in which the intralobular branches terminate (Plate XX. fig. 2, *b*.); 2nd, those in which no intralobular branches terminate (Plate XX. fig. 2, *c*.). The lobules are arranged around the veins composing the first set, the bases of these bodies resting upon them; they may be called the sublobular-hepatic veins, this term being applied to them merely to distinguish them from the trunks which compose the second set, and on which the bases of the lobules do not rest. The branches of the second set are formed by the junc-

* De Glandularum secernentium Structurâ penitiori earumque primâ Formatione in Homine atque in Animalibus. Lipsiæ 1830.

tion of those of the first; the canals containing the former differ in the manner of their formation from those containing the latter. Every branch of the hepatic veins contained in the liver belongs to one of these two classes of vessels.

Each intralobular vein is composed of a central vessel, and of from four to six or eight smaller vessels, which terminate in the central vessel. (Plate XX. fig. 3, *e. f.*) The intralobular veins invariably correspond in form with the lobules, the substance of which is arranged around them; and as these vessels resemble in some degree the fibres of a leaf, so sections of the lobules made in the direction of the vessels assume a more or less foliated appearance. (Plate XX. fig. 3, *b.*) The lobules are not, however, flattened bodies like leaves; for, as the smaller veins enter the central vein in every direction, so small processes project in every direction from the lobules, the number of processes being equal to the number of veins terminating in the central vein. The form of the lobules will be now easily understood; their dimensions are known to all anatomists. They are small bodies, arranged in close contact around the sublobular-hepatic veins, each presenting two surfaces. One surface of every lobule, which may be called its base, rests upon a sublobular vein, to which it is connected by the intralobular vein running through its centre, the base of the lobule thus entering into the formation of the canal in which the sublobular vein is contained. (Plate XX. figg. 3. and 4, *c.*) The canals containing the hepatic veins may be called the hepatic-venous canals or surfaces; and as the base of every lobule rests on a sublobular vein, it is evident that the canals containing these veins are formed by the bases of all the lobules of the liver. (Plate XX. fig. 4, *h.*) The external or capsular surface of every lobule (Plate XX. figg. 3. and 4, *d.*) is covered by an expansion of Glisson's capsule, by which it is connected to, and separated from, the contiguous lobules, and in which branches of the hepatic duct, portal vein and hepatic artery ramify. All the lobules resemble each other in their general form, and they are all of nearly equal dimensions; they appear larger when the section is made in the direction of the hepatic veins, and smaller when in the transverse direction. This is most apparent in that state of the liver usually called the nutmeg liver. In a longitudinal section of a lobule, the intralobular vein is seen running through its centre; and if on the surface of the section five of the projecting

processes of the lobule be seen, five smaller veins will also be seen, one occupying the centre of each process, and all terminating in the central vein. (Plate XX. figg. 3. and 4, *f*.) In a transverse section of a lobule, the divided extremity of the intralobular vein is seen in the centre, and three or four processes of the lobule are seen shooting out in different directions. (Plate XX. fig. 6.) The vein being thus always situated in the centre, it sometimes happens that on the surface of a section of the liver, veins are seen in some lobules and not in others; this appearance is caused by the instrument, which, passing obliquely through these lobules, divides some vessels, which thus become apparent, and passes either above or below others.

The superficial differ in one respect from the internal lobules. In the latter, the intralobular veins commence at a certain distance from the surfaces of these bodies, the substance of which completely surrounds them, except at the bases of the lobules, where the veins make their exit to terminate in the sublobular veins. (Plate XX. fig. 5, *c*.) By superficial lobules are meant, not those only which form the convex and concave surfaces, but those also the capsular surfaces of which form the canals containing certain branches of the hepatic duct, portal vein, and hepatic artery, and the canals containing the trunks of the hepatic veins, all these canals being tubular inflections inwards of the superficies of the liver. In all the superficial lobules, the intralobular veins commence immediately at the surfaces; these lobules appearing less perfect in form, or less developed, than those of the interior, or as if their upper portions had been removed, giving to the surfaces of the organ the appearance of the surface of a section. (Plate XX. fig. 5, *d*.) The knowledge of this peculiar form of the superficial lobules enables us, in injecting the hepatic veins, to limit the injection to this system of vessels, which is effected by withdrawing the syringe when the injection appears in minute points on the surface of the liver. If the injection be propelled from the hepatic veins into those portions of the lobular venous plexuses immediately surrounding the intralobular veins, the first stage of hepatic venous congestion will be simulated; this is effected by withdrawing the syringe when the injection appears in small isolated patches on the surface. The next stage of congestion will be simulated by propelling the injection until the patches partially coalesce, and become continuous with each other; and finally, the appearance of general congestion is produced when the injection

passes into those branches of the portal vein which ramify in the interlobular fissures. Occasionally double lobules, or lobules having two intralobular veins, are observed on the surface. (Plate XX. fig. 7.)

Mascagni *, adopting Malpighi's view of the arrangement of the lobules, compares the liver to a bunch of grapes; and this anatomist and Bidloo have represented the lobules appended to the extremities of the vena portæ. As certain branches of this vein first ramify between the lobules, and finally enter them, these bodies may be represented as appended to its extremities: and although every lobule receives branches from this vein, yet a certain number only are clustered around its trunks, with which they have no immediate connexion; whereas the base of every lobule in the liver is in contact with, and connected to, an hepatic vein.

The essential part of a gland is undoubtedly its duct; vessels it possesses in common with every other organ; and it may be thought that in the above description too much importance is attached to the hepatic veins: but relations similar to those which exist between these veins and the lobules, do not exist between the latter and the ducts, or between them and any other set of vessels; nor is there the same exact relation between the ducts and lobules as between these bodies and the hepatic veins, for a lobule with six projecting processes may have three times that number of ducts ramifying on its external surface, whereas the same lobule will have but six minute veins, one in each process, all of which terminate in the central intralobular vein.

The foliated appearances delineated by Müller †, resemble very closely the lobules as I have described them; but they are not lobules, nor are they described as such by this anatomist. The figure representing the structure of the liver of the squirrel resembles longitudinal sections of lobules in some parts, and transverse sections in other parts. Vessels similar in their course to the intralobular branches of the hepatic veins are seen in this figure; but the vessels here represented are interlobular branches of the portal vein; and had the duct and artery been injected, small branches of these vessels also would have been seen accompanying the branches of the vein. The vein is seen occupying a fissure, which at intervals is dilated into spaces; these, as will be shown, are the interstices between the lobules. In those parts of the same figure which

* Prodromo, p. 142. tab. vi. fig. 17.

† Op. cit. tab. xi. figg. 8, 9, 11.

Fig. 1.

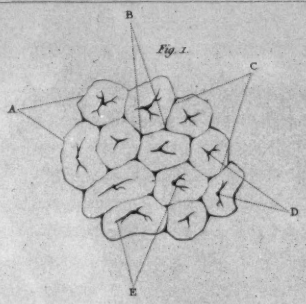


Fig. 2.

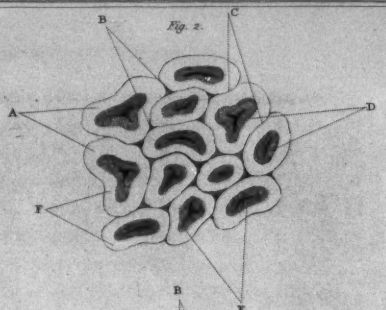


Fig. 3.

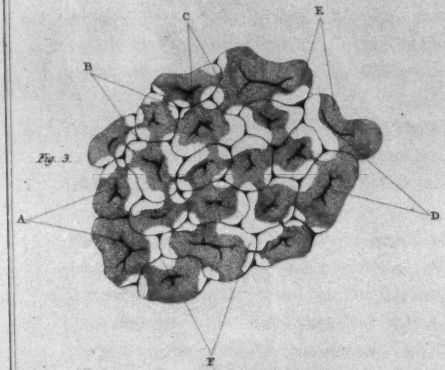


Fig. 4.

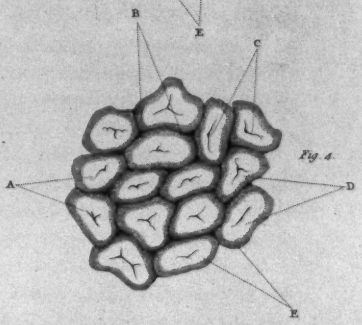


Fig. 5.

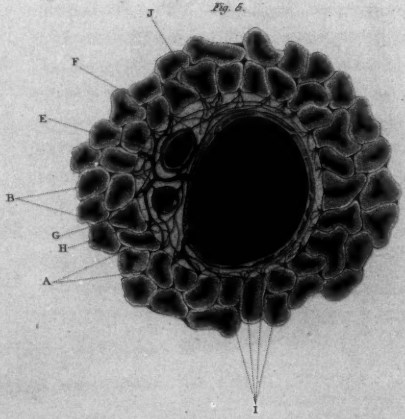
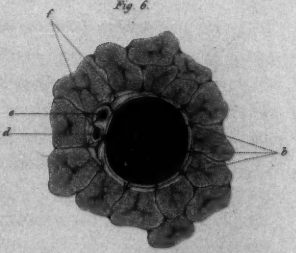


Fig. 6.



resemble transverse sections of lobules, the central dark spot is an interlobular space, occupied by branches of the duct, portal vein and hepatic artery. Had the animal died from hemorrhage, or had the portal vein and hepatic artery been tied in the living animal, so as to deprive the liver of its blood, no such appearances would have presented themselves, the arrangement of the structure of the liver in this, and in all the vertebrated animals, being much alike. I have preparations accurately exhibiting these appearances, which very commonly present themselves in the human liver, as well as in the liver of animals, and are produced by congestion, principally of the hepatic veins, the lobules being also congested except at their opposed margins. The same remarks apply to the delineations given by this anatomist of the liver of the quail, and to that of a portion of the human liver.

Of the Surfaces of the Liver.—The surfaces of the liver are, 1st, the external surface; 2ndly, the portal surfaces or canals, at which the vessels enter the organ; 3rdly, the hepatic-venous surfaces or canals, at which the vessels make their exit.

Of the External Surface.—Examined on the external surface of the liver, the lobules present every variety of form; but in one subject they may all be more or less angular, and in another rounded. They are separated from each other by fissures, which, at the angles of the lobules, dilate into small triangular spaces; they may be called the interlobular fissures and spaces; they contain the interlobular branches of the portal vein, hepatic artery and hepatic duct, ramifying in a fine cellular tissue continuous with Glisson's capsule, which, with the vessels, constitutes the capsules of the lobules. (Plate XXI. fig. 1, *b* and *c*.) The fissures and spaces were known to MALPIGHI: he was of opinion that by their means the liver is rendered flexible, and he tells us they are large in fishes, "qui flexuosè incedunt." He also informs us that the fissures were known to his predecessor CORTESIUS *, to FERNELIUS †, to GLISSON ‡, and others.

* "Hic enim foramina quædam, seu rimulas in jecoris carne deprehendit."—De Hepate, cap. 2.

† "FERNELIUS rimulas in hepatis parenchymate observavit."—Ib.

‡ GLISSON appears to allude to the clefts so frequently seen on the surface of the liver, and not to the interlobular fissures. "Vidi aliquando in gibba quorumdam jecinorum parte rimas et hiatus majusculos qui fortè à partium extremarum violentiore complicatione ortum duxerant: quemadmodum et panis frustrum nimiâ incurvatione diffringitur."—Anatomia Hepatis, cap. 9.

Mappes * has described the fissures and spaces; but this anatomist is mistaken in supposing that some of them contain hepatic veins alone, and that others contain hepatic veins, arteries and ducts. When there is but little cellular tissue in the capsules, the lobules are closely compacted together; they are therefore angular in form, and the fissures and spaces are less apparent. (Plate XXI. fig. 1.) Hence it is that these bodies have been described as having six or more sides by Malpighi, Sœmmerring †, and others. But when the cellular tissue composing the capsules is more abundant, the fissures, and particularly the spaces containing it, are wider and more apparent; the lobules are less closely connected, they touch each other by two or three points only, and consequently approach more or less to the circular or oval form. (Plate XXI. fig. 2.) Hence they have been described as, and present very much the appearance of, convolutions and undulating bands ‡. They are generally angular where they are most numerous, as in the thickest part of the liver; in these parts also they appear smaller, for being arranged vertically to the surface, their extremities alone are seen. At the edges of the liver, where they are fewer in number and less closely connected, they are rounded; and lying in an oblique or parallel direction to the surface, they appear larger. They are more angular in children than in adults: in some animals, as in the cat, they are always more angular than in others, as in the rabbit, hare and sheep; their angular or rounded form always depending on the quantity of cellular tissue composing Glisson's capsule. They appear smaller, are more equal in size and regular in form on the convex than on the concave surface of the liver, where they are arranged obliquely, the hepatic veins for the most part running nearer to this surface.

* "Au milieu de toutes les circonvolutions de cette substance (la substance jaune) se trouvent la plupart du temps des ouvertures triangulaires, ou un peu frangées, qui communiquent les unes avec les autres par de petites fentes."—Quelques Considérations sur la Structure du Foie,—Journal Complémentaire des Sciences Médicales, tom. xii. p. 223.

† "Idem, si in superficie aut in plagâ aliquâ dissectâ attentiùs consideraveris, ex acinis parvis quodammodo triquetris, tetragonis, pentagonis, hexagonis ac multangulis compositum videtur."—De Corporis Humani Fabricâ, vol. vi. p. 175.

‡ "L'une de ces substances, qu'on peut appeler granulée (médullaire suivant Autenrieth), forme des circonvolutions, tantôt semblables à celles des intestins, tantôt rameuses, plates et arrondies."—Mappes, loc. cit.

An intralobular hepatic vein occupies the centre of each superficial lobule *. If the extremity alone of a lobule reach the surface, a mere point will be seen in its centre; if a greater portion of the lobule be seen, two or three dark lines will be observed uniting together at a dark point; this point is the central intralobular vein in which the smaller veins terminate. (Plate XXI. fig. 1, *d* and *e*.) Frequently, lobules with eight or ten projecting processes are found on the surface, each process sending a vein to the intralobular vein running through the centre. It is evident that these superficial lobules are less perfect in form or less developed than the internal lobules, in which the veins are wholly surrounded by the substance (Plate XX. fig. 5, *d*.); and that a superficial lobule with eight or ten processes is, accurately speaking, half a lobule lying parallel to the surface. Lobules lying parallel to the surface may be always seen on the under and posterior part of the left lobe; such lobules are larger and more numerous in the liver of the sheep, rabbit, hare and squirrel than in the human liver. (Plate XX. fig. 1.) A striking difference will be observed if, in the liver of the sheep, these parallel lobules on the posterior part of the concave surface be contrasted with those forming the lobulus Spigelii. The difference between the superficial and internal lobules is satisfactorily proved by injections. If the hepatic veins be injected with blue size, and the portal vein with red, the blue will be found on the surface of every section, in the centres of the lobules, separated by the substance of these bodies from the portal veins occupying the interlobular fissures. If these lobules were, like those of the surfaces, perforated from one extremity to the other by the intralobular veins, the blue and red injection, or the intralobular hepatic veins and the interlobular portal

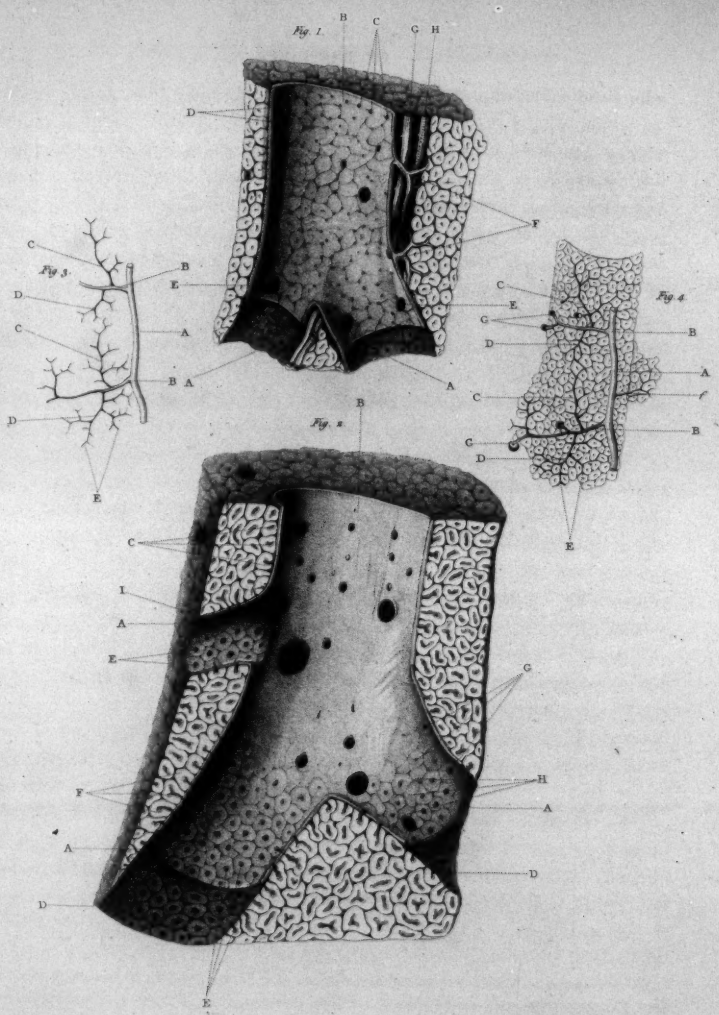
* These vessels, which are not mentioned by Ruysch, Haller, Morgagni, Ferrein, or by any other anatomist with whose works I am acquainted, did not escape the observation of Malpighi. "Ad singulos autem hosque minimos lobulos, prout experiri licet, et ex pluribus etiam colligere, multiplices vasorum rami derivantur; nam surculi venæ cavæ, et portæ, porique biliarii indeficienter per totum hepatis corpus ramificantur, ut luculenter etiam Glissonius, in nondum satis laudato hepatis opere nobis indicat, et sanguineum vas in lobulis extimam hepatis superficiem constituentibus, *è centro ejusdem erumpens*, hinc inde ramificatur per totam periferiam bifidos promens ramos, à quo totus lobulus irrigatur."—De Hepate, cap. 2. And in his Opera Posthuma, p. 30, after speaking of the lobules, he says, "In horum centro scissura excitato sanguineo vasi extra erumpenti aditum præbet, quod in contiguas minimas glandulas, quibus lobuli quique integrantur, extremis finibus propagatur." It appears, however, that Malpighi mistook these branches of the hepatic vein for branches of the portal vein, and that he was acquainted with them in the superficial lobules only.

veins, would, in some places at least, be seen in contact, which is never the case.

The veins and fissures cannot be always seen without the aid of a magnifying glass; slight pressure, however, by which the blood is propelled into them, will generally make them visible. They may be always seen after a few hours maceration in water, or they may be shown by mercurial or size injections. For this purpose a liver containing the smallest quantity of blood should be chosen; and on this account the liver of the sheep is preferable to the human liver, the latter being generally in a state of congestion. The vena cava should be opened at its posterior part, and the mercury should be poured from a quill into the hepatic vein of the lobulus Spigelii. With slight pressure the mercury will appear in the centres of the lobules, in the form of lines, stellæ or points, surrounded by what has been called the red substance of the liver. If the liver contain much blood, the experiment may not succeed, for the blood will be propelled to the surface, and the vessels within the lobules will be no longer distinguishable from those between them. If the pressure be discontinued, the elasticity of the vessels will cause the mercury to retreat from the surface; if the pressure be renewed and slightly increased, the mercury will pass from the intralobular branches of the hepatic vein into the interlobular branches of the portal vein, and will be seen in the centre and at the circumference of every lobule. If the mercury be thrown into a branch of the portal vein, it will appear in the interlobular branches situated in the fissures and spaces. In the portal veins, which ramify in the cellulo-vascular capsules of the lobules, the mercury will have a dull appearance; it will be of its usual brilliancy in the intralobular veins, which, contained within the lobules, have no cellular tissue surrounding them.

Of the Portal Canals.—These canals commence at the transverse fissure, where they are continuous with the concave surface of the liver; they contain the hepatic ducts, the portal veins, the hepatic arteries, and the vaginal branches of all these vessels, with the nerves and absorbents, enveloped in a sheath of cellular tissue, first described by Glisson, and called Glisson's Capsule *. If

* The right edge of the lesser omentum is usually called Glisson's Capsule in this country. Glisson, after describing the suspensory ligament, says, "Ligamentum hoc non solùm extimæ hepatis



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a longitudinal section of one of these canals be made, and the contents be dissected out, lobules, spaces and fissures will be seen, arranged in a precisely similar manner to those already described on the external surface. The lobules forming the parietes of the canals are similar to those of the surface, being, like them, perforated by the intralobular veins: they may be called the portal canals or surfaces, the portal vein being the largest vessel contained in them. (Plate XXII. fig. 1, *a*.) These canals, and those containing the large hepatic trunks, are formed by the capsular surfaces of a limited number of lobules; the canals containing the sublobular-hepatic veins are formed by the bases of all the lobules.

Glisson's capsule has attracted much of the attention of anatomists. It was known to Walæus* before it was described by Glisson; to the latter anatomist, however, who has given a detailed account of it, it owes all its celebrity. He describes it as a prolongation of the suspensory ligament, which enters the liver for the purpose of supporting its weight†; he says it arises from the peritoneum, and is of a particular structure‡; he considers it as the muscular coat of the portal vein, by which the blood is propelled through the liver §. Glisson supports his opinions respecting the structure and functions of the capsule with much ingenuity; they were admitted by Malpighi ‖, were, according to Haller ¶, strongly advocated by Pozzi, and generally adopted by anatomists until their fallacy was exposed by Fanton** and others. Haller†† and Sabatier‡‡ considered the capsule as a prolongation of the cellular tissue

membranæ affigitur, sed etiam parenchyma ejus penetrat, et communi vaginæ sive involucro rami venæ portæ (quà vena umbilicalis eidem continua est) validè adnectitur."—Anatomia Hepatis, cap. 2.

* "Imò in ipso hepate, tot rami arteriæ sunt, quot sunt rami venæ portæ, et totidem quoque sunt rami ductûs cholidochi. Quæ omnia hactenus ab anatomicis pro venis portæ habitæ sunt, quòd communi tunica tria illa vasorum genera in hepate includantur."—Jos. Walæus, De Motu Chyli et Sanguinis, ad T. Bartholinum Epistola Secunda: 1640.

† Op. cit. cap. 2. ‡ Ibid. cap. 28. § Ibid. cap. 42. ‖ De Hepate, cap. 2.

¶ "Josephus Pozzi in Commentariolo Epistolico pro glandulis hepatis, et Glissonianæ capsulæ carneis fibris, pugnat."—Methodus Studii Medici, vol. i. p. 373.

** Brevis Manuductio ad Historiam Anatomicam Corporis Humani, p. 109: Taurini 1699.—Dissertationes Anatomicæ, p. 135: 1701. Haller says, "G. Cowperus, capsulam Glissonii primus, ni fallor, demonstravit parvi momenti esse."—Methodus Studii.

†† "Nempe vena portarum multam cellulosam telam ex mesenterio et liene secum adfert."—Elementa Physiologiæ, vol. vi. lib. 23.

‡‡ Traité d'Anatomie, tom. iii. p. 350.

which surrounds the vessels in the mesentery and lesser omentum. Laennec *, after describing the proper capsule of the liver, which had been previously described by Sabatier † and Sœmmerring ‡, the latter of whom calls it the *membrana cellulosa hepatis*, says, that this membrane, having covered the surfaces, enters the tissue of the liver, furnishing sheaths to all the vessels distributed to it, one of which, common to the vena portæ, biliary ducts and hepatic artery, constitutes Glisson's capsule. The capsule, he continues, is intimately connected with the substance of the liver, and is separated from the vessels by a loose and abundant cellular tissue, which is continuous with that surrounding the sinus of the vena portæ in the transverse fissure, and is connected with that of the mesentery; it is also continuous with that which connects the proper capsule with the peritoneum. Laennec is of opinion that Glisson's capsule allows the portal vein to yield and accommodate itself to the increased quantity of blood circulating through it during digestion. If it be true that more blood circulates through the liver during this period than at any other, which is denied by Bichat §, yet Laennec's explanations of the function of the capsule cannot be admitted, for the hepatic veins would be equally subject with the portal vein to these variations in the circulation; the former vessels are, nevertheless, firmly connected to the substance of the liver, having no sheath of cellular tissue around them.

The cellular tissue of Glisson's capsule is undoubtedly continuous with that of the proper capsule of Laennec, and with the cellular tissue which surrounds the abdominal vena portæ, as described by Haller and Sabatier; but, as M. Roux ‖ observes, "il faut admettre quelque chose de plus dans ce qu'on nomme *capsule de Glisson*, puisqu'elle est tellement disposée que les vaisseaux qu'elle enveloppe sont lâchement unis à la substance du foie." Glisson's capsule is not mere cellular tissue: it is to the liver what the pia mater is to the brain; it is a cellulo-vascular membrane, in which the vessels divide and subdivide to an extreme degree of minuteness; which lines the portal canals, forming sheaths for the larger vessels contained in them, and a web in which the

* Laennec, Lettre sur des Tuniques qui enveloppent certains Viscères,—Journal de Médecine, par Corvisart, tom. v. p. 539.

† Traité d'Anatomie, tom. ii. p. 345 : 1791.

‡ De Corporis Humani Fabricâ, vol. vi. p. 168.

§ Anatomie Générale, tom. ii. p. 248.

‖ Bichat, Anatomie Descriptive, tom. v. p. 98.

smaller vessels ramify; which enters the interlobular fissures, and, with the vessels, forms the capsules of the lobules; and which finally enters the lobules, and, with the blood-vessels, expands itself over the secreting biliary ducts. Hence arises a natural division of the capsule into three portions, a vaginal, an interlobular, and a lobular portion; and as the vessels ramify in the capsule, their branches admit of a similar division.

At the transverse fissure, the duct, vein and artery divide into branches, which enter the portal canals. These branches divide and subdivide into smaller branches, which enter smaller canals, and every canal, however small, contains one principal branch of each of these vessels; frequently, however, two ducts and two arteries are contained in the same canal. To these larger vessels the terms of hepatic ducts, portal veins and hepatic arteries may be confined, in order to distinguish them from the branches.

The excreting ducts are composed of the hepatic ducts, contained in the canals, of their vaginal branches, also contained in the canals, and of the interlobular branches, which, arising from the vaginal branches, ramify in the interlobular fissures. The interlobular ducts enter the lobules, in which they form plexuses. These plexuses may be called the lobular biliary, or secreting biliary plexuses, the ducts composing them being the secreting organs of the bile. The excreting ducts and their branches are invariably accompanied by the arteries and portal veins and their branches, the former conveying blood to their coats, the latter conveying it from them; a duct is never unaccompanied by an artery and vein, the vein being always a branch of the portal vein. The veins and arteries also enter the lobules. The veins form plexuses, the branches of which terminate in the intralobular hepatic veins; from the blood circulating through the plexuses, the bile is secreted. The lobular arteries are exceedingly minute, and few in number; they are the nutrient vessels of the lobules, and probably terminate in the plexuses formed by the portal vein. From the ducts, veins and arteries, therefore, three sets of branches arise, namely, the vaginal, the interlobular, and the lobular branches.

Of the Vaginal Portion of Glisson's Capsule and of its Vessels.—A branch of each vessel, contained in a portal canal, makes its exit from the canal at each interlobular space on its surface. The lobules being small bodies, the interlobular spaces are necessarily numerous and close together. The hepatic duct

and artery running together on one side of the canal, or winding spirally within it, are in apposition with but a very limited number of spaces; the two vessels are, however, brought into apposition with all the spaces by means of plexuses, from which the interlobular branches arise. (Plate XXI. fig. 5, *f. h.*) The portal vein also forms a plexus, being separated from the spaces by the duct and artery and their plexuses. (Plate XXI. fig. 5, *d.*) The branches forming these plexuses are the first which arise from the duct, artery and vein; they form a vascular sheath around these vessels, and may be called their vaginal branches; they ramify in a loose and fine cellular tissue, which, with them, constitutes the vaginal portion of Glisson's capsule. (Plate XXI. fig. 5, *j.*) This cellular tissue is continuous with that surrounding the vessels in the right edge of the lesser omentum, and with that of the proper capsule of Laennec. The internal surface of the cellulo-vascular sheath is in contact with the three principal vessels, and is composed of the largest branches arising from them. Its external surface is in contact with the parietes of the canal, and is composed of the smallest branches; these branches form a reticulated plexus, from which the interlobular branches shoot out, and entering every interlobular space, ramify between the lobules. (Plate XXI. fig. 5, *i.*) In the smaller canals, the fissures and spaces being less numerous, and the plexuses formed by the duct and artery being consequently less complicated, a great portion of the portal vein is in contact with the parietes of the canal. In these canals many of the interlobular veins arise immediately from the trunks, vaginal branches being given off, and forming a plexus, on that side only of the canal occupied by the duct and artery. In these canals we find the capsule, the essential part of which is the plexus, only on that side which is occupied by the duct and artery, the vein being in contact on the opposite side with the parietes of the canal. In the larger canals, in which the lobules and spaces are more numerous, and the plexuses necessarily more complicated, the sheath completely surrounds the three vessels. These two modes of arrangement of the capsule may be ascertained by making transverse sections of canals of different calibre. In a small canal in which the capsule is found only on that side occupied by the duct and artery, the portal vein should be laid open, and its internal surface examined. The fissures and lobules will be seen through the transparent coats of the vein on that side on which there is no capsule, and on the internal

surface of the vein numerous minute orifices will be observed, corresponding exactly to the interlobular spaces. These orifices are the mouths of interlobular veins, which enter the spaces without contributing to the formation of the plexus. (Plate XXI. fig. 6, *b*. Plate XXII. fig. 1, *c*.) A few larger orifices, not corresponding to the spaces, will also be seen: these are the mouths of vaginal branches, which divide in the canal into two, three, or more interlobular branches, and thus contribute partially to form the plexus. (Plate XXII. fig. 1, *d*.) On that side of the vein which is in contact with the artery and duct, and separated by them from the spaces, the orifices are larger and less numerous; these are the mouths of vaginal branches, which, ramifying in the canal, terminate in interlobular branches, which enter those spaces covered by the duct and artery. (Plate XXI. fig. 6, *c*. Plate XXII. fig. 1, *f*.)

From the above description it is evident that Glisson's capsule is a cellulo-vascular membrane, composed of the vaginal branches of the duct, vein and artery, ramifying in a layer of cellular tissue. Its existence around the three vessels in the larger canals, in which the vaginal plexus is most complicated; its existence on that side only of the smaller canals occupied by the duct and artery, and its almost total absence on the opposite side, sufficiently prove that by its means the three vessels are brought into apposition with all the interlobular spaces on the surfaces of the canals. The vaginal vessels are best seen by making longitudinal sections of canals, and dissecting out the three large vessels after having injected them. The mouths of the interlobular branches arising from the smaller portal veins may be shown by opening a vessel and removing the injection carefully from the trunk, leaving it in the branches. The internal surfaces of the ducts and arteries exhibit no orifices of interlobular branches, these branches always arising from the plexus which each duct and artery, however small, forms in the canal in which it is contained. The portal vein, like other vessels, occasionally varies in the manner in which it gives off its branches; thus, even in the smallest canals, it frequently happens that the three vessels are surrounded by the capsule. In this case the vein gives off vaginal branches only, and no interlobular branches, all the latter arising from the former.

The first vaginal branches of the ducts arise at nearly right angles with the trunks; they run in a transverse direction within the inner surface of the canal,

and terminate in branches which correspond to, and lie on, the fissures. Each transverse branch gives off one or two branches which ramify in the direction of the trunk, and one or two recurrent branches. All these branches run in the direction of the fissures, forming angles at the spaces over which they pass. At each angle a smaller branch is given off, which runs on a fissure leading from the space over which the angle in the vessel is formed. Thus, if the vessels be well injected, all the fissures and spaces will be covered by small ducts, which form a network of vessels corresponding in form to the fissures on which they lie. The transverse branches, and those which arise immediately from them, do not anastomose with each other, but the smaller branches sometimes appear to do so; I cannot, however, from dissection, affirm that they do, for those which appear to anastomose are exceedingly small vessels, and meet each other at the spaces; hence it is difficult to ascertain whether they really anastomose, or enter the spaces together without anastomosing. From the vaginal ducts spread over the surface of the canal, lobular and interlobular ducts arise; the former enter the lobules on the parietes of the canals; the latter leave the canals at the spaces to ramify between the lobules, which they finally enter. (Plate XXII. figg. 3. and 4.) The vaginal ducts are sometimes very tortuous in their course.

The coats of the ducts are highly vascular; the rugæ on their internal surface, and those on the internal surface of the gall-bladder, are formed by the ramifications of the larger blood-vessels, arteries as well as veins, covered by the mucous membrane. This membrane is studded with vascular papillæ, which become remarkably developed in the diseased ducts so frequently found in sheep and oxen. The smaller ducts are furnished with papillæ only, and to the rupture of the delicate vessels forming these papillæ is to be attributed the facility with which Sœmmerring and other anatomists injected the ducts from the arteries and veins, and not to any direct communication between the vessels and the ducts. This point has been particularly insisted upon by Müller, who, in speaking of Walter's experiments, says, "Itaque si in Walteri experimentis massa interdum ex vasis sanguiferis in ductum hepaticum transiit, certe non per minimos ductus biliferos transiit, sed in truncos ipsos ex vasculis sanguiferis erupit*." Mappes imagines that the hepatic artery is principally destined to

* Op. cit., p. 83.

Fig. 1.

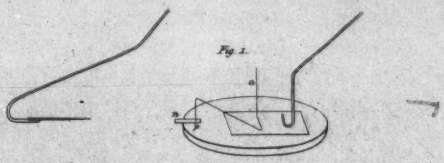


Fig. 2.

Fig. 3.

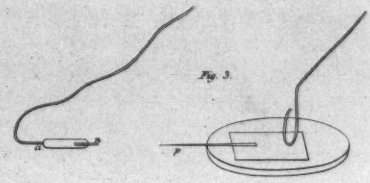


Fig. 4.

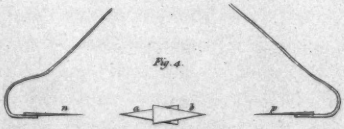


Fig. 5.

Fig. 6.

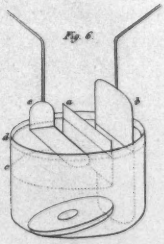
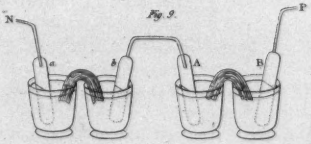


Fig. 7.

Fig. 8.

Fig. 9.



supply the coats of the portal vein with blood: this is so far from being the case, that when the arteries are well injected, the larger ducts, from the extreme vascularity of their coats, may be mistaken for the injected arteries, whilst, in the coats of the vein, no vessels will be detected without the aid of the magnifying glass*. The coats of the ducts may be as highly injected from the portal vein as from the hepatic artery; but they cannot be injected from the hepatic veins, if the injection is confined to these vessels, and does not return by the portal vein. Mappes could not inject the ducts from the portal or hepatic vein; he is nevertheless of opinion, "que la bile est tirée plutôt du sang déjà parvenu dans cette veine (la veine hépatique) que de celui qui se trouve encore dans les dernières extrémités de la veine porte." The ducts cannot be injected in a direct manner from the hepatic vein, no branches of this vein ramifying in their coats; fluid may indeed be made to pass from this vein into the ducts, but only through the medium of those branches of the portal vein which ramify in the coats of the ducts†. The ducts are injected from the portal vein and from the hepatic artery in the same manner as the fœtal intestine is frequently filled with injection from the umbilical vein or aorta, viz. by the rupture of the minute vessels of the mucous membrane. Hence it is evident that the ducts, so far as they have been yet traced, are abundantly supplied with arterial blood; that this blood returns into the branches of the portal, and not into those of the hepatic veins; and that the hepatic portal vein has branches of origin in the coats of the excreting ducts from the terminations of the hepatic artery, as the abdominal portal vein arises in the coats of the intestines, in the spleen and pancreas, from the arteries of these organs.

From their extreme vascularity alone we might infer, that the ducts serve

* Mappes probably saw the vaginal arteries, which ramify on the parietes of the canal previously to entering the interlobular spaces, through the transparent coats of the veins, and concluded that they were ramifying in the coats of these vessels; or in making sections, this anatomist may have removed a portion of the parietes of a canal, leaving the arteries on the vein.

† By examining the surface of the liver after injecting the hepatic veins, we may ascertain in which parts the coats of the ducts are injected from these vessels, and in which they are not. If on one portion of the surface we see the interlobular portal veins injected from the hepatic veins, a few injected vessels will be found in the coats of the ducts of this part. In other parts of the liver, where the injection is confined to the centres of the lobules, and consequently to the hepatic veins, no injection will be found in the coats of the ducts, although the injected hepatic veins will be seen through them.

another purpose beside that of the conveyance of bile; and all anatomists are acquainted with the muciparous follicles of the lining membrane of their larger branches; in the smaller branches, the existence of the follicles has been denied*. In the former, they are irregularly distributed over the surface; in the latter, they are closely arranged in two longitudinal lines, occupying opposite sides of the ducts; and, arranged in this manner, they will be found in the smallest duct that can be examined. Mappes confounded the follicles with the orifices of vessels. Their number renders it probable that the fluid furnished by them serves another purpose beside that of rubricating the surfaces of the ducts†. Some estimate of the quantity of this fluid may be formed by examining the ducts, after having injected them with alcohol. These follicles are probably the secreting organs of all the mucus found in the bile. (Plate XXIII. fig. 1.)

The vaginal ducts are accompanied by the vaginal arteries; the latter, however, are more or less tortuous in their course, the former generally proceeding in the shortest direction to their destination. The vaginal arteries anastomose freely with each other, but their ramifications do not, like those of the ducts, correspond exactly to the fissures. If the left artery be injected in the transverse fissure, the injection will return by the right artery; this communication takes place by means of vaginal branches which the left artery gives off in the fissure, and which anastomose with similar branches of the right artery.

The vaginal branches of the vein anastomose with each other; they form a much more complicated plexus in the human liver than in the liver of most animals, and on this account the cellular tissue of Glisson's capsule is more abundant in the former, and greater difficulty is experienced in examining the plexuses formed by the ducts and arteries. In the sheep, portal veins of considerable size resemble the smaller portal veins in the human subject, vaginal branches arising from them on that side only of the canal occupied by the duct and artery, and interlobular branches on the other side. On this side,

* Meckel, Op. cit., tom. iii. p. 455.

† The internal surface of the pancreatic duct is studded with follicles similar to those of the hepatic ducts; they assume no particular arrangement. They are numerous and very apparent in some subjects; in others I have found no trace of them. The parotid and submaxillary ducts are not furnished with follicles.

Fig. 1.

Fig. 2.

Fig. 3

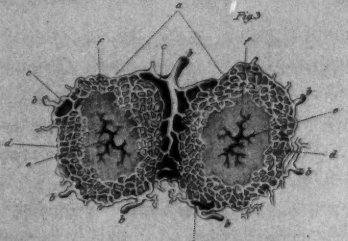


Fig. 4.

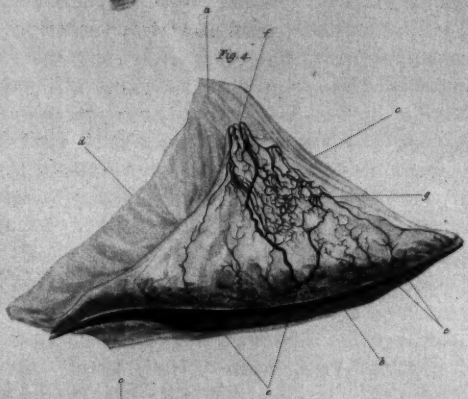


Fig. 5.

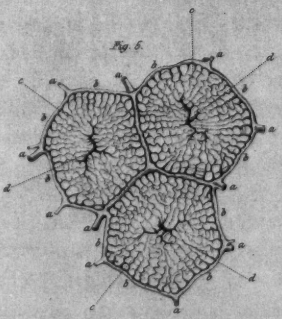
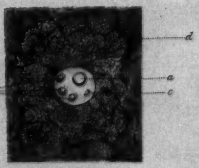


Fig. 6.



therefore, we find the cellular tissue in small quantity, no venous plexus being formed, and the injected vaginal ducts and arteries may be seen without dissection through the transparent coats of the vein.

The nerves and deep-seated absorbents ramify in the portal canals; I have not been able to trace them into the interlobular fissures. The absorbents may be always injected from the duct, and the bile is frequently propelled into the former vessels by injecting the latter. Mascagni * found that injection thrown into the ducts returned colourless by the absorbents. I have frequently made the same observation, but I have as frequently found the injection in the absorbents of the same colour as that thrown into the duct, and have frequently filled all the absorbents of the right edge of the lesser omentum with red size from the duct. In one instance, and in the only one in which the trial was made, the thoracic duct was injected with mercury from the hepatic duct. Lippi asserts that "the lymphatics terminate not only, as has been hitherto supposed, in the thoracic duct and in the right subclavian vein, but that an infinite number of communications exist between the veins and lymphatics in other parts of the body †." Antommarchi ‡ asserts that no such communications take place; and Lippi's opinions appear to have been satisfactorily refuted by Panizza §. No absorbents accompany the hepatic veins, and it is not probable that any of the absorbents of the liver terminate in the branches of the portal vein, the fluids in these two systems of vessels proceeding in different directions. The superficial absorbents ramify in the proper capsule. After injecting these vessels, the peritoneal coat may be removed without injuring them; or the peritoneal coat may be first removed, and the absorbents afterwards injected; and some few may be injected in the proper capsule after the separate removal of both. This can be done in the human subject and in the larger animals only, the proper capsule being of a much more delicate structure, or probably not existing, in the smaller animals, in which the liver appears to have no superficial absorbents. Injection sometimes passes from the arteries and portal veins into the absorbents.

Of the Interlobular Portion of Glisson's Capsule and of its Vessels.—As the interlobular ducts, veins and arteries arise from the vaginal ducts, veins and

* Prodromo della Grande Anatomia, p. 141.
† Illustrazioni del Sistema linfatico-chilifero, p. 10.
‡ Journal Hebdomadaire, tom. iv. p. 214.
§ Annali Universali di Medicina, vol. lvi. p. 225.

arteries, so the interlobular cellular tissue is continuous with the vaginal cellular tissue, the vessels and cellular tissue together constituting the interlobular portion of Glisson's capsule, which occupies the fissures and forms the capsules of the lobules *. The interlobular vessels, at their origin from the vaginal vessels, enter the spaces; in the spaces, therefore, we find the largest branches; these divide into smaller branches, which ramify in the fissures.

If the left hepatic duct be injected with size or mercury, the injection will return by the right duct, without extravasation and without passing into other vessels, and the injection will be found in the interlobular and vaginal ducts as well as in the trunks. This communication between the two ducts does not take place, like that which exists between the right and left arteries, through the medium of the vaginal branches of the transverse fissure, the injection being found in interlobular branches arising from the right duct. From this experiment, which I have frequently repeated with the same result, it appears that the right and left duct anastomose with each other through the medium of the interlobular ducts. This experiment does not always succeed, which probably arises from the quantity of bile contained in the ducts.

The interlobular branches of the portal vein cover, with their ramifications, the whole external surfaces of the lobules, with the exception of the bases of these bodies, and of those extremities of the superficial lobules which appear on the surfaces of the liver. The freest communications take place between these vessels; when successfully injected, which can be done with size only, the interlobular fissures in which they are contained, whether examined on the surfaces of the liver, or on the surface of a section, are coloured with the injection. Mercury thrown into a large branch of the portal vein returns by other large branches. This communication takes place through the medium of the interlobular branches, for though the vaginal branches in the same canal anastomose freely with each other, yet those of one canal communicate with those of another through the medium of the intervening interlobular branches alone. The interlobular veins also form communications between the lobular

* The interlobular portion of Glisson's capsule is thus accurately described by MALPIGHI: "Lobuli hi propriâ circumambiente membranâ vestiuntur, et continuatis per transversum membranosis nexibus firmantur, ita ut intermedia spatia, et rimulæ, minimæ tamen, inter lobulorum latera emergant." —De Hepate, cap. 2.

veins of a lobule, and those of the contiguous lobules. Hence it appears, contrary to the assertions of Bichat* and Mappes†, that the freest anastomoses exist between all the branches of the portal vein, and that the interlobular branches form the medium of communication.

When the portal vein is imperfectly injected, and the venous circles, formed by its interlobular branches around the lobules, are not brought into view, these branches are seen in the spaces, and three or four smaller branches are seen shooting into the fissures communicating with the spaces. These are the stellated vessels of anatomists. When the vessels are well injected, the stellæ are all continuous with each other, and the venous circles are formed; the stellated appearance, therefore, arises from the incomplete injection of the vessels. If the liver do not contain much blood, stellæ may be always produced on its surface by pressure.

No anastomoses can be shown to exist between the interlobular arteries, these vessels, even when most successfully injected, appearing like points, lines and stellæ in the fissures and spaces. The right artery may be injected from the left in the transverse fissure, and it has been shown that this communication takes place by means of the vaginal branches given off by the two arteries in the fissure; but if the left artery, or a branch of it, be injected at its entrance into its canal, after the vaginal branches of the fissure are given off, the injection will not return by the right artery. From this experiment it would appear that no anastomoses take place between the interlobular arteries; but as the vaginal arteries communicate freely with each other, and as the interlobular ducts also communicate with each other, and as the arteries ramify in the coats of the ducts, we may conclude that the interlobular arteries anastomose.

From the superficial interlobular fissures, small arteries emerge and ramify in the proper capsule on the convex and concave surfaces of the liver, and in the ligaments. These are the capsular arteries. They vary much in number in different subjects, being always most numerous in those in which the capsule is most developed. In those animals in which the liver has a peritoneal

* Speaking of the anastomoses of the portal vein, Bichat says, "Sa portion hépatique paraît en manquer: toutes les branches, rameaux et ramuscules, marchent isolément."—Anatomie Générale, tom. ii. p. 247.

† Loc. cit.

coat only, and no proper capsule, no capsular arteries can be shown by injection. In those subjects in which the capsular arteries are numerous, these vessels cover the surfaces of the liver with a beautiful plexus: those of the right lobe anastomose with those of the left, and both anastomose with branches of the phrenic, internal mammary and supra-renal arteries; some, leaving the liver, ramify under the peritoneum covering the right kidney; others pass along the ligamentum teres to the umbilicus, and anastomose with the epigastric arteries.

Walter did not distinguish the proper capsule, described by Sœmmerring and Laennec, from the peritoneal coat of the liver, the latter of which, he says, has no vascular connexions with the liver, but receives vessels from the vessels of the peritoneum, which, according to this anatomist, are branches of the internal mammary, epigastric, phrenic, intercostal and lumbar arteries. In his most successful injections of the vessels of the liver, Walter could detect no vessels in the peritoneal coat "nec nudo nec armato oculo, sed apparuit hæc membrana ut in hepatibus non injectis, alba neque vasis picta *." Walter erroneously concludes that this membrane has proper vessels, arising from the sources above enumerated, and having no connexion with those of the liver. All the capsular arteries, arising from whatever source, ramify in the proper capsule, and they may be all injected from the hepatic artery. I have never seen injected vessels in the peritoneum, but as recent adhesions between the liver and diaphragm may be injected from the hepatic artery, it appears evident that the peritoneal coat of the liver is nourished by this artery. That the proper vessels of the liver anastomose with those which Walter calls the proper vessels of the membrane, is proved by the fact, that recent adhesions between the right lung and the diaphragm may be injected from the hepatic artery, the injection passing from the capsular branches of this vessel into those of the phrenic, and thence into the phrenic arteries themselves †. The capsular veins are branches of the portal vein; these vessels communicate freely with branches of the phrenic veins. In some cases of atrophy of the liver, and in cases in which the circulation through the liver has been for some time obstructed, a

* De Hepate, p. 88.

† The capsular arteries have been well delineated by Ruysch, Thesaurus Anatomicus Decimus, No. 181. tab. 3. fig. 5.

collateral circulation is established by means of the communications which take place between the capsular branches of the hepatic artery and portal vein and those of the phrenic artery and vein.

All the *vasa vasorum* of the liver are branches of the hepatic artery and portal vein. Branches of the artery ramify in the coats of the duct, artery and portal vein; veins arise in the coats of all these vessels, and terminate in branches of the portal vein. In the hepatic-venous canals, and in the fissure of the inferior cava, small arteries issue from the interlobular fissures, and ramify in the coats of the hepatic veins and inferior cava; veins arise in the coats of these vessels, and entering the interlobular fissures, terminate in branches of the portal vein. All the veins arising in the coats of the vessels, and terminating in the portal vein, constitute the hepatic origin of this vein.

The trunks of the duct, vein and artery in each canal, terminate in interlobular branches. Vaginal vessels, giving off interlobular vessels, ramify in the transverse fissure, in the fissure of the gall-bladder, and in that containing the obliterated umbilical vein and ductus venosus; these fissures, therefore, must be considered as portions of portal canals.

Of the Hepatic Veins, and of the Hepatic-venous Canals.—The hepatic veins are contained in canals, which may be called the hepatic-venous canals; they commence in the interior of the liver, and terminate at the fissure of the inferior cava. Those containing the hepatic trunks are formed by the capsular surfaces of a limited number of lobules; those containing the sublobular-hepatic veins, are formed by the basis of all the lobules.

As three vessels are contained in each portal canal, and as a branch of each vessel makes its exit from the canal at each interlobular space, each vessel necessarily forms a plexus, by which it is brought into apposition with all the spaces on the surface of the canal: but one vessel only, an hepatic vein, being contained in each hepatic-venous canal, the external surface of the vein is in contact with, and connected to, all the lobules forming the parietes of the canal, the intralobular veins, at their exit from the lobules, entering the sublobular-hepatic veins without uniting in the canals to form branches similar to the vaginal branches of the portal vein, duct and artery. The interlobular branches of the vein and artery conveying blood to the lobules, correspond to the intralobular branches of the hepatic veins, which convey the blood from

the lobules; the former arise from the vaginal branches, the latter terminate in the sublobular-hepatic veins. Thus we find that the hepatic veins have no branches corresponding to the vaginal branches of the duct, portal vein and artery; and as Glisson's capsule is composed of the vaginal vessels ramifying in cellular tissue, we consequently find nothing similar to this capsule around the hepatic veins, these veins having no vaginal branches. In the smaller portal canals, in which the spaces are less numerous and the plexus less complicated, one side of the portal vein is in contact with the parietes of the canal. On this side the interlobular branches arise immediately from the vein, and the cellular tissue is in small quantity, forming a delicate membrane on the walls of the canal; on the opposite side, which is separated from the walls by the duct and artery, vaginal branches arise from the vein, and the cellular tissue is abundant. (Plate XXI. fig. 6.) These smaller portal veins resemble the hepatic veins on that side on which they are in contact with the walls of the canal, on which no vaginal branches are given off, on which the interlobular branches arise immediately from them, and on which there is no capsule; they resemble the larger portal veins on that side on which vaginal branches arise from them, and on which the capsule consequently exists. From the absence of vaginal branches on one side of these portal veins, it may be presumed, that should a portal vein be found entering the liver unaccompanied by a duct and artery, it would, like the hepatic veins, be connected to the parietes of its canal, and would, like these vessels, have no vaginal branches, and, consequently, no capsule. The structure and uses of Glisson's capsule are now fully explained, it being evident that the loose connexion of the ducts, portal veins, and hepatic arteries to the substance of the liver arises from the circumstance of the three vessels ramifying in the same canals; and that the adhesion of the hepatic veins to the substance depends on one vessel only being contained in each hepatic-venous canal.

Numerous minute orifices are seen on the internal surface of the sublobular-hepatic veins; these orifices are the mouths of the intralobular veins, all of which terminate immediately in these vessels*. Every orifice corresponds to

* The orifices of the intralobular veins are most distinctly shown by injecting the hepatic veins with coloured size, by then making longitudinal sections of the veins and removing the injection from them, leaving it in the intralobular branches.

the centre of the base of a lobule; the number of orifices is therefore equal to the number of lobules forming the parietes of the canal in which the vein is contained. (Plate XXII. fig. 2, *e*.) As an intralobular vein makes its exit from the base of every lobule, and as every intralobular vein terminates in a sublobular vein, it is evident that the base of every lobule is in contact with a sublobular vein, and that the hepatic-venous canals containing these vessels are formed by the bases of all the lobules of the liver. The parietes of the portal canals are also composed of lobules; but they are composed of the capsular surfaces of lobules, and not of the bases, nor do all the lobules enter into their formation as into that of the hepatic-venous canals; for, as the interlobular ducts, veins and arteries ramify in fissures continuous with each other throughout the liver, many of these vessels terminate in lobules situated at a distance from the trunks from which they arise, these distant lobules not contributing to form the canals containing the trunks. As all the lobules unite to form the hepatic-venous canals, and as a certain number only enter into the formation of the portal canals, it is evident that the former are more numerous than the latter.

In the description of the lobules, the hepatic veins contained in canals were divided into two sets, into the sublobular-hepatic veins, and the hepatic trunks. The coats of the former are delicate in texture; they are transparent; the lobules and fissures are seen through them; their internal surface is studded with the orifices of intralobular veins; their canals, which are formed by the bases only of lobules, are not lined by prolongations of the proper capsule. (Plate XX. fig. 2, *b*. Plate XXII. fig. 2, *a*.) The trunks are more dense in structure; their external coat is composed of longitudinal bands; their canals are lined by prolongations of the proper capsule, which render them opake, the lobules and fissures not appearing through them; they receive no intralobular branches. Dense in structure, they are not adapted to receive these minute and delicate veins; their canals, therefore, unlike those containing the sublobular veins, are, like those containing the portal veins, composed of the capsular surfaces of lobules, the intralobular veins of which terminate in a neighbouring sublobular vein. (Plate XX. fig. 2, *c*. Plate XXII. fig. 2, *b*. *c*.)

If the internal surface of the large veins, which open into the trunks, be examined, and contrasted with the internal surface of a sublobular vein, the

orifices of the intralobular veins will be found less closely arranged in the former than in the latter. (Plate XXII. fig. 2, *g. h.*) This appearance arises from two causes. Two or three intralobular veins at their exit from the lobules, frequently unite and form one vein, which terminates in the large vein, on the internal surface of which will be seen one larger orifice, instead of three smaller orifices. Frequently also on the surfaces of these canals the capsular surfaces of lobules are seen, the bases of which enter into the formation of a neighbouring canal; no orifices, therefore, corresponding to the bases of these lobules are found in the veins under examination.

The intralobular veins will almost invariably be found entering the sublobular veins from the centre of what has been called the red substance of the liver. (Plate XXII. fig. 2, *e.*)

Of the formation of the hepatic-venous canals it may be said, that the smallest of the canals, and the greater number of them, are formed by the bases alone of lobules; that the next in dimensions are formed by the bases of some, and the capsular surfaces of other lobules; and that the largest are formed by the capsular surfaces only of these bodies. As the base of every lobule rests on a sublobular-hepatic vein, it is evident that those lobules, the capsular surfaces of which enter into the formation of canals, are in contact with two hepatic veins.

Ramifying in fissures which are continuous with each other throughout the whole liver, the interlobular branches of the portal vein anastomose freely with each other, enveloping every lobule in a venous web: the intralobular branches of the hepatic veins, on the contrary, confined within the lobules, have no direct communication with the corresponding branches of the surrounding lobules, from which they are separated by the substance of these bodies, and by the intervening interlobular ducts, veins and arteries, situated in the interlobular fissures; and one intralobular vein can be injected from another only through the medium of the intervening portal veins. When injected with mercury or size, the intralobular veins appear in the centres of the lobules in the form of points, stellæ, or twigs; these veins, therefore, unlike the interlobular portal veins, do not anastomose with each other. If, by means of a pipe and glass tube, mercury be thrown into a large hepatic vein on the surface of a section, it will return by several smaller neighbouring hepatic veins, which, generally, are

branches descending to terminate in the larger vessel in which the pipe is fixed. If these vessels be tied, the mercury will return by large hepatic veins, situated at a distance from the injected vessel, and not branches of it. In this experiment the force used is not sufficient to propel the mercury through the intervening intralobular, lobular and interlobular veins, and by such means to form a communication between the two hepatic veins; for if force sufficient to effect this were used, the mercury would return by portal as well as by hepatic veins, which is not the case. If the inferior cava be opened at its posterior part, and if by the same means mercury be thrown into a small hepatic vein, it will immediately return to the cava by other hepatic veins, without appearing in the superficial intralobular veins, and without passing into portal veins. From these experiments it appears that the sublobular veins anastomose with each other, and that their intralobular branches do not*.

By contrasting the hepatic veins with the portal vein, we find that no two intralobular branches of the former anastomose with each other; that the interlobular branches of the latter form one continuous plexus throughout the whole liver; that the sublobular veins anastomose directly, and not through the medium of the intralobular branches; that the portal veins have no direct communication with each other, but anastomose by means of their interlobular branches; that the hepatic veins, like the other veins of the body, proceed in a direct course to their termination in the cava; that the portal vein, accompanied by an artery, resembles an artery in its ramifications; that the larger hepatic veins, having longitudinal fibres in their coats, differ in structure from the portal vein; and that the blood contained in the liver after death is almost invariably found in the hepatic veins, the portal vein being usually empty.

The longitudinal fibres in the coat of the larger hepatic veins are similar to those in the coats of the iliacs and inferior cava, and to those which are occasionally seen in some superficial veins. Those of the iliacs and cava have been delineated by Senac†, who says they are composed of muscular fibres. This

* The most superficial vessel, the intralobular branches of which are seen on the surface, should be chosen for these experiments, and in order to ascertain that the mercury does not pass into the portal vein, a section of the liver should be made at some distance below the injected vessel. A glass tube and pipe, whereby the pressure may be graduated, should be always used in these experiments. Size injected into one hepatic vein will always, and wax will sometimes, return by other hepatic veins.

† Traité de la Structure du Cœur, tom. i. p. 254. Pl. IV. fig. 3.

opinion, which was adopted by PORTAL*, is sufficiently refuted by the existence of similar fibres in the hepatic veins, which, being firmly connected to the substance of the liver, admit of no motion.

The hepatic veins in the *Seal* differ in many respects from those of any other animal I have examined. The intralobular veins at their exit from the lobules do not, as in other animals, terminate immediately in the hepatic veins: these vessels enter the hepatic-venous canals, where they unite into branches, which, like the vaginal branches of the portal vein, are connected by a fine cellular tissue, with which they form around the hepatic veins a cellulo-vascular sheath, precisely similar to that surrounding the branches of the portal vein. The structure of the two sheaths is similar, but their uses are different. That of Glisson's capsule has been explained; the capsule of the hepatic veins in the seal appears destined to admit of the muscular contractions of these vessels. The posterior cava in this animal forms at the back part of the liver a large sinus in which the hepatic veins terminate, and which, according to CUVIER, "is connected with the power of diving, which these animals possess in a high degree†." The external coat of the hepatic veins is composed of circular fibres, which in the larger vessels form a complete tunic. In the smaller vessels the fibres are arranged in the form of circular fasciculi, which are connected with each other by oblique intermediate fibres. All the fasciculi do not extend completely round the veins; some, dividing into two portions, unite with fibres from those above and below, and form other fasciculi. (Plate XXIII. fig. 2.) By contrasting the hepatic veins in the seal with those in the human subject, it would appear that the circular bands in the former are composed of muscular fibres. In man, the fibres are longitudinal; in the seal, they are circular: in the former, the vessels adhere firmly to the parietes of their canals; in the latter, they are loosely connected by the cellulo-vascular sheath in which they are inclosed. The existence of the sinus in which these veins terminate, and in which the blood accumulates during the act of diving, appears to indicate the necessity of a muscular power to propel the blood onward to the heart. Had the intralobular veins in the seal terminated, as in other animals, immediately in the hepatic veins, these vessels would have been connected to every lobule forming the parietes of their canals, and their muscular contractions could not

* Anatomie Médicale, tom. iii. p. 348. † Leçons d'Anatomie Comparée, tom. iv. p. 265.

have taken place; the use of their sheaths is therefore evident, and different from that of the portal vein, hepatic duct and hepatic artery. No circular fibres exist in the coats of any of the other veins of this animal.

In the *Porpoise* the hepatic veins are connected to their canals; no circular fibres are seen in their coats. Their external surface is reticulated, the ridges corresponding to the interlobular fissures, where the interlobular cellular tissue is continuous with the cellular coat of the veins. The mouth of an intralobular vein occupies the centre of each space circumscribed by the ridges.

In diving birds, CUVIER says*, "all that portion of the vena cava inclosed in the liver is of very considerable diameter, and forms a kind of reservoir similar to that in the seal." I have examined some birds of this class, but have found no circular fibres in their hepatic veins.

Of the Structure of the Lobules.—The lobules constitute the secreting portion of the liver. Examined with the microscope, a lobule is apparently composed of numerous minute bodies, of a yellowish colour (imparted to them by the bile they contain) and of various forms, connected with each other by vessels. These minute bodies are the *acini* of MALPIGHI; his opinions respecting their structure and use are well known. RUYSCH† admitted the existence of the acini, and, more successful in his injections than MALPIGHI, he filled the minute vessels which are described by the latter anatomist as ramifying between these bodies; he thereby, probably, rendered the acini invisible, or less apparent than they present themselves in the natural state, in which they had been discovered by MALPIGHI, and he concluded that these minute bodies are composed of the terminal extremities of the vessels, with a certain number of which the ducts are continuous. BOERHAAVE‡ attempted to reconcile the contending opinions of the two great anatomists. FERREIN§ successfully opposed these opinions; he demonstrated the tubular structure of the kidney, and was the first who asserted that several other viscera, the liver, spleen and renal capsules, "sont un assemblage merveilleux de tuyaux blancs, cylindriques différemment repliés." MASCAGNI‖ says the liver is composed of cells, from which the minute biliary ducts arise, and this anatomist enters into a description of

* Op. cit., tom. iv. p. 274.

† Epistola Anatomica ad H. BOERHAAVE.

‡ Epistola Anatomica ad F. RUYSCH.

§ Mémoires de l'Académie Royale des Sciences, 1749.

‖ Prodromo, p. 142.

the various tunics of which these supposed cells are composed. To Müller, whose recent discoveries have thrown much light on the ultimate structure of glands, is due all the merit of the important discovery, that a gland is a duct, with blood-vessels ramifying on its parietes. This anatomist asserts, from analogy rather than from actual demonstration, that the biliary ducts in the vertebrated, like those in some of the invertebrated animals, terminate in cæcal extremities, which present certain differences in the manner of their arrangement in the different classes. The foliated and pinnate appearances delineated in Müller's 11th plate, and displaying, according to this anatomist, the manner in which the terminal extremities of the ducts are arranged, appear to me to result solely from partial congestion of the liver, the foliated portions being composed of the non-congested opposed edges of lobules, with the interlobular ducts, veins and arteries ramifying between them*. This state of the organ I have represented in Plate XXI. fig. 3. Appearances somewhat similar to those represented by Müller, Tab. XI. fig. 11, have been delineated by Dr. Hope in his valuable work on Morbid Anatomy. In describing figg. 104 and 105, Dr. Hope says†, "The acini or white substance of the liver displayed with singular and unusual distinctness: from a case in which the vena portæ was plugged with coagula and fibrinous concretions. The acini were very small, pale and collapsed, as if they had lost a portion of their supply of blood, thus allowing the red substance which occupied a preternatural space to encroach upon and compress them." The small bodies represented in these figures are composed of non-congested portions of three contiguous lobules, "the small puncta or depressions in the centre" being interlobular spaces, containing branches of the duct, portal vein and artery. These bodies being neither acini nor lobules, and the branches of the portal vein here represented being situated between, and not in, lobules, it cannot, from these appearances at least, be inferred, as Dr. Hope inquires, "that the principal part of the portal blood is distributed to the acini." MM. Boulland and Andral, Dr. Hope, and most other anatomists, are of opinion that the liver is composed of two substances,—of a red and a yellow substance: it will be shown hereafter that these two apparently different substances are identical in structure, the red colour resulting from congestion only.

* Op. cit. † Part V.

The portal vein enters the liver in all the vertebrated animals, in all of which the lobules are arranged around the hepatic veins as I have described them in man. Each lobule is composed of a plexus of biliary ducts, of a venous plexus formed by branches of the portal vein, of a branch of an hepatic vein, and of minute arteries; nerves and absorbents, it is to be presumed, also enter into their formation, but cannot be traced into them.

The hepatic ducts, commonly so called, and their vaginal and interlobular branches constitute the excreting portion of the biliary apparatus; they are also organs of mucous secretion, being furnished with mucous follicles: the secreting portion of the liver is also composed of ducts, which form a plexus in each lobule. These plexuses may be called the lobular biliary, or secreting biliary plexuses. The ducts composing them being exceedingly minute, and always containing bile, much greater difficulty is experienced in injecting them than in injecting the blood-vessels of the liver, even in the usual manner; and this difficulty is not so easily overcome as that occasioned by blood in the vessels, for the bile contained in the excreting ducts is propelled by the injection into the secreting ducts, from which it has no exit by other vessels, and consequently opposes the entrance of the injection. This process is, to a certain degree, facilitated by tying the portal vein and hepatic artery in the living animal, and thereby arresting the secretion of the bile *. If this operation be carefully performed, the animal will survive several hours, during which time the ducts will discharge much of the bile they contained, and the liver will sometimes become almost colourless. The experiment will probably be attended with more success if performed a few hours after feeding the animal. After preparing the liver in this manner, I have frequently succeeded in partially injecting the lobules from the hepatic duct; I have also injected these bodies from the duct in the human subject, but with less success. Examined with the microscope, the injected interlobular ducts are seen dividing into branches, which, entering the lobules, divide and subdivide into minute ducts; these ducts anastomose with each other, forming a reticulated plexus. (Plate XXIII. fig. 3.) If an uninjected lobule be examined and contrasted with an injected lobule, it will be found that the acini of MALPIGHI in the former are

* It is probable that the *tubuli seminiferi* might be injected with facility in animals after arresting the secretion, by dividing the blood-vessels of the cord several days before killing the animal.

identical with the injected lobular biliary plexus in the latter, and the blood-vessels in both will be easily distinguished from the ducts. The ducts forming the plexuses, when examined with the microscope, present very much the appearance of cells; and this appearance, which has been well delineated by Mascagni *, probably induced this anatomist to consider the liver as an assemblage of minute cavities, giving origin to the ducts. The form of the lobules bears no relation to the arrangement of the ducts, the form of each lobule being always correspondent to the branches of the intralobular hepatic vein occupying the centre of the lobule. The coats of the lobular ducts, on which the blood-vessels next to be described ramify, constitute the proper secreting substance of the liver, as the coats of the cortical ducts of the kidney, and those of the tubuli seminiferi, constitute the secreting substance of their respective organs.

The left lateral ligament may be considered as a rudimental liver, in which this organ presents itself to our examination in its simplest form. From that edge of the liver connected to the ligament, numerous ducts emerge, which ramify between the two layers of peritoneum of which the ligament is composed. These ducts were discovered by Ferrein, but this anatomist did not ascertain their termination. "A l'égard des vaisseaux biliaires, M. Ferrein en a observés de nouveaux, dont les uns reviennent du ligament gauche du foye, et qu'il a vûs quelquefois repandus sur la face inférieure du diaphragme †." These ducts, the smallest of which are very tortuous in their course, divide, subdivide and anastomose with each other. They are sometimes exceedingly numerous, two or three of them in such cases being of considerable size; some of them, as Ferrein says, frequently extend to the diaphragm and ramify on its inferior surface. They sometimes extend only half-way up the ligament, where they divide into branches, which, forming arches, return and descend towards the liver, anastomosing, or being continuous, with other ducts issuing from it. The spaces between the larger, or excreting, ducts are occupied by plexuses of minute, or secreting, ducts. (Plate XXIII. fig. 4.) I have injected the ducts on the inferior surface of the diaphragm, but have not succeeded in injecting them to their termination; we may however conclude,

* Prodromo, Tab. VI. figg. 13, 14.

† Mémoires de l'Académie Royale des Sciences, Histoire, 1733.

that, like those just described, they form arches, the branches returning towards the ligament, and being continuous with others ascending from it. Branches of the portal and hepatic veins, with arteries and absorbents, also ramify in the ligament, which, including between its layers a plexus of secreting and excreting ducts, with blood-vessels ramifying on their parietes, admirably displays the structure of the liver*. Ferrein speaks of other ducts; "d'autres reviennent de cette portion des parois de la veine cave, qui paroît hors de l'échancrure sigmoïde du foye quand on le regarde par derrière, d'autres enfin reviennent des membranes de la vésicule du fiel." The inferior cava usually occupies a fissure at the back part of the liver; this fissure is frequently converted into a canal by a portion of the liver, extending from the lobulus Spigelii to the right lobe; frequently, also, the fissure is converted into a canal by a band, apparently of ligamentous texture, varying in width in different subjects. This band is, like the left lateral ligament, a transparent portion of the liver, containing ducts and blood-vessels. In a preparation in my possession, in which the ducts in this band are injected, a few injected ducts are seen issuing from the right lobe and ramifying on the coats of the cava above the band. The umbilical vein is also contained in a fissure, which is frequently converted into a canal by a process of the liver, called the *pons hepatis*, extending from the *lobulus quadratus* to the left lobe; sometimes the two lobes are connected by a band only, which is similar in structure to that behind the cava. No ducts ramify in the coats of the gall-bladder. It is probable that Ferrein mistook the absorbents of the gall-bladder for ducts, this anatomist, probably, having injected some of the former vessels, as I have frequently done, from the hepatic duct: or Ferrein may allude to ducts which occasionally ramify between the liver and gall-bladder, and divide into interlobular branches, which enter the former, and which he may have removed with the latter and mistaken for ducts ramifying upon it. No branches of the hepatic veins ramify in the coats of the gall-bladder; and the absence of these vessels sufficiently proves the non-existence of ducts. The cystic veins are branches of the abdominal portal, and not of the hepatic portal or umbilical, vein: they are therefore efferent, and not afferent, vessels, conveying blood from, and not to, the

* A beautiful preparation is made by drying the ligament on glass, after having injected the ducts with size or mercury.

gall-bladder: it necessarily follows, that biliary ducts ramifying on the parietes of this receptacle would receive the materials of their secretion from arterial blood,—that of the cystic arteries. If in any case ducts should be found on the gall-bladder, I venture to assert, that branches of both the portal and hepatic veins will also be found; but the portal veins in such a case will be branches of the hepatic portal vein, will convey blood from the coats of the excreting ducts, and to the coats of the secreting ducts, and not from the gall-bladder. If ducts, arteries, and one set only of veins, terminating in either the portal or hepatic veins, should be found,—and this is always the case if Ferrein's assertion, that ducts ramify on the coats of the gall-bladder, be true,—then would the bile of these ducts at least be secreted, beyond dispute, from arterial blood.

Branches of the hepatic artery and portal vein accompany the ligamentum teres; these veins convey blood to the hepatic portal vein, and must therefore be considered as separate branches of the abdominal portal system.

Of the Lobular Venous Plexuses.—The interlobular branches of the portal vein, surrounding the lobules on every side except at their bases, divide into branches, which, entering these bodies, form in each of them a plexus, the branches of which terminate in the intralobular hepatic situated in the centre of the lobule. This plexus, interposed between the interlobular portal veins and the intralobular hepatic vein, constitutes the venous part of the lobule, and may be called the lobular venous plexus. Examined with a powerful microscope, the vessels constituting the plexus are seen converging from their origin at the circumference toward their termination at the centre of the lobule; they communicate with each other by smaller transverse branches, between which are seen minute circular, ovoid, or oblong spaces, occupied by portions of the lobular biliary plexus. (Plate XXIII. fig. 5.) Examined with a less powerful microscope, the vessels of the plexus appear arranged in circles. The circular, ovoid and oblong portions of the biliary plexus, seen between the branches of the venous plexus, are the acini of Malpighi. Müller has delineated the converging vessels of the plexuses in the liver of the squirrel; but this anatomist did not ascertain whether they were branches of the portal vein or of the hepatic artery. "Præsertim examinare juvat, utrum vascula sanguinea descripta, inter acinos elongatos decurrentia, ad venam portarum an ad arterias pertineant, num sanguis inter acinos diffusus eadem ratione inferius

in venulas colligatur. Doleo, Sciurum hactenus novum defuisse, in quo quæstiones hæce vasis artificiose repletis possent extricari*." The venous plexus of one lobule communicates with the plexuses of the surrounding lobules by means of the intervening interlobular branches of the vena portæ, this vein thus forming one continuous plexus through the whole liver. The converging branches of each plexus unite at the centre of each lobule, and form an intralobular hepatic vein, this vein having no communication with the corresponding veins of the contiguous lobules, except through the medium of the intervening plexus and portal veins. No branches of the hepatic veins are found in any other part of the liver; occupying the centre alone of each lobule, their only office is to convey the blood from the lobular venous plexuses, and not from the arteries.

In consequence of its double venous circulation, the liver is naturally in a state of sanguineous congestion; hence arises the great difficulty of making successful injections of the human liver: the plexuses may, however, be frequently well, but seldom equally, injected, and always with greater success from the portal, than from the hepatic vein, the latter, and those portions of the plexuses immediately surrounding its intralobular branches, generally containing whatever blood may remain in the liver after death. The plexuses may be always injected with facility from the portal or hepatic veins, and the injection will pass freely from one vein into the other without extravasation, if the liver has been previously deprived of all its blood by the ligature of the portal vein and hepatic artery in the living animal†. Anatomists have consi-

* Op. cit., p. 80.

† I for some time experienced great difficulty in making successful injections of the minute vessels of the liver; and this difficulty, arising from the presence of blood in the vessels, was increased when my object was to inject the two veins in the same organ, no exit being then left for the blood. Very little advantage is gained by previously injecting warm water, a large portion of which remaining in the vessels dilutes the injection and obstructs its course. The object is to obtain a free passage for the injection through the minute vessels; this can be accomplished only by tying the portal vein and hepatic artery in the living animal, and thus depriving the liver of all its blood. In one minute after the application of the ligature, the liver becomes bloodless, and the sufferings of the animal may be abridged, and regurgitation into the hepatic veins prevented, by dividing the inferior cava near its termination in the right auricle. Before injecting, the body of the animal should be left in water during twenty-four hours, a ligature having been previously placed on the inferior cava above the diaphragm to prevent the entrance of the water into the hepatic veins. If the liver be previously prepared in this manner, all the intralobular hepatic veins may be injected with one colour, and all the interlobu-

dered, that the free communications which exist between the two vessels obviate the difficulty which would otherwise arise in the circulation through the liver, from the want of power consequent on the presence of the two veins*; and although the communications between these vessels appear, upon experiment, to be more free than those which exist between the hepatic artery and the portal vein, and between arteries and veins generally in other parts of the body, yet it appears that the arteries and veins in the spleen and kidney, and probably in all glands, communicate with equal freedom. The lobular venous plexus is best examined in the superficial lobules, but here again the human liver presents a difficulty, particularly in the adult, in consequence of the opacity of the proper capsule: the liver of the cat, and that of the smaller animals generally, appear to have no cellular capsule, and are consequently more favourable for this purpose.

The venous plexus ramifies on the biliary plexus: the blood circulating through it is composed of the portal blood, and certainly of that portion of the arterial blood which, having nourished the excreting ducts and supplied them with mucus, and having circulated through the vasa vasorum of all the vessels, becomes venous and is received into the branches of the portal vein, by which, with the portal blood, it is conveyed to the plexus; and from this mixed blood the bile is secreted.

The vessels of the plexus ramify on, or as Müller says, between, the se-

lar portal veins with another, and the course and distribution of each set of vessels may be studied with facility. The various appearances produced by congestion of the liver may be imitated by injection. This method of injecting is equally applicable to every other organ. I made a very successful injection of the portal and hepatic veins in the exsanguine liver of a man, who died from the rupture of an aneurism of the abdominal aorta, under the care of Dr. Hope, in the Marylebone Infirmary. In the preparations of this liver, as in those made by injecting the vessels after the ligature of the portal vein and hepatic artery in living animals, the central portions of the lobules are coloured with blue, and the marginal portions with red injection.

* The *vis à tergo* is removed by the ligature of the portal vein and hepatic artery; these vessels, nevertheless, disembarrass themselves perfectly of their blood, and no regurgitation takes place. In the sheep, the inferior cava runs in a direction parallel to the superior margin of the liver, a part of the right lobe of which is in front of this vein: the hepatic veins conveying the blood from this part terminate in the cava at obtuse angles; this blood consequently flows in an opposed direction to that passing through the cava. The collision of the two currents is prevented, and a septum is, to certain distance, formed between them by two valves, somewhat larger than those of the human aorta, situated at the orifices of the two right hepatic veins.

creting ducts; they are not continuous with the ducts as was imagined by Ruysch. On this subject Müller observes: "Itaque autopsia docet, vascula sanguifera tenuissima cum ductibus biliferis cæcis nullum commercium inire*.....Neque verò quisquam commercium inter fines ductuum biliferorum et vascula sanguifera unquam observavit. Quod jam Hallerus rectè monuit. Nemo vidit vasculum sanguiferum in finem ductûs biliferi usquam desinens†."

Of the Lobular Arteries.—The lobules are sparingly supplied with arterial blood. These bodies cannot be coloured with injection from the artery even in the young subject; in the adult, after the most successful injection, when the arteries of the cellular capsule, those of the excreting ducts and gall-bladder, and the vasa vasorum are minutely injected, a few injected vessels only are detected entering the lobules. I have frequently tied the thoracic aorta in living animals, thereby cutting off all supply of blood from the abdominal viscera; and in these animals, when injected from the aorta below the ligature forty-eight hours after death, the integuments, the secreting portions of the kidneys, the spleen, pancreas, intestines and pelvic viscera were coloured in a remarkable degree by the injection; on the surface of the liver a few vessels only could be discovered, this organ presenting a curious contrast with the surrounding coloured viscera. The gall-bladder and ducts were, however, equally well injected with the intestines; the vasa vasorum were also well injected. In these experiments it will be remarked, that the secreting portion alone of the kidney was highly injected; the excreting portion of this gland resembling the secreting portion of the liver in its supply of arterial blood, which it receives for nutrition only. Similar experiments were tried on birds, and in these animals all the viscera were highly injected, with the exception of the liver and kidneys, the latter organs in oviparous animals having, like the liver, a double venous circulation, the urine, as well as the bile, being secreted from venous blood‡. Whether the liver be injected from the aorta or from the hepatic artery, the appearances produced will be nearly the same. In

* Op. cit., p. 82. † Ibid. p. 83.

‡ Jacobson, De Systemate Venoso peculiari in permultis Animalibus observato. Hafniæ 1821. "On a peculiar Arrangement of the Venous System observed in many Animals," Edinburgh Medical and Surgical Journal, vol. xix. p. 78.

speaking of the excreting ducts, it was shown that these vessels are abundantly supplied with arterial blood, which is received by branches of the portal vein; the injection very commonly passes from the arteries into these branches, and thence into the trunks of the vein, and it occurred to me, that the injection thrown into the arteries was probably in this manner diverted from the lobules. To ascertain if such was the case, blue injection was first thrown into the portal vein; the arteries were then injected with red. On dissection, branches of the two sets of vessels were found in the coats of the vessels, and in those of the excreting ducts and gall-bladder; the lobules were coloured with the blue injection; the red was confined to their circumference, and appeared in points only. This experiment was varied by injecting the portal vein and its branches as far only as the entrance of the latter into the lobules, these bodies thus remaining uninjected. The injection propelled through the arteries had now free access to the uninjected lobules, and no exit by the injected portal vein; and the artery having no communication with the hepatic veins, the injection had no exit by these vessels: the lobules, however, were not better injected in this than in the preceding experiments. From these experiments I conclude, that the secreting portion of the liver, like the excreting portion of the kidney, is supplied with arterial blood for nutrition only. As all the branches of the artery of which we can ascertain the termination end in branches of the portal vein, it is probable that the lobular arteries terminate in the lobular venous plexuses formed by that vein, and not in the intralobular branches of the hepatic veins, which cannot be injected from the artery, the blood of these arteries, after having nourished the lobules, becoming venous, and thus contributing to the secretion of the bile.

Müller is also of opinion that the ultimate reticulated vessels of the liver receive blood from the artery as well as from the portal vein: "Vascula ultima reticulata sanguinem tam ab arteriis quam à venâ portarum accipere, venisque hepaticis reddere, ex hisce argumentis concludo: 1. Post injectionem in arteriam hepaticam non minùs quàm in venam portarum aut venas hepaticas factam, eadem communia vasculorum minimorum retia replentur, quod ex injectionibus exsiccatis Lieberkühnianis, Berolini asservatis, facilè quisquis sibi persuadebit:" from which it appears that Lieberkühn injected the lobules from the artery, as well as from the portal or hepatic veins. I have

shown that the ultimate reticulated vessels, or those I have called the lobular venous plexuses, are formed by the portal vein alone; that the branches of the artery ramify in the coats of all the vessels; and that these arteries terminate in the branches of the portal vein: it would appear, therefore, that LIEBERKÜHN, if he injected the lobules from the artery, must have previously filled all the branches of the portal vein from that vessel*. MÜLLER's second argument is: "Injecti liquores colorati ex alio vasorum ordine facilè in aliud transeunt, qualis frequens HALLERI veterumque, WALTERI denique et RUDOLPHII cet. extat experientia. Ipse equidem transitum aquæ limpidæ et coloratæ sæpius observavi†." MÜLLER coincides in opinion with those anatomists who suppose that all the blood-vessels communicate directly with each other. I have shown that no branches of the artery terminate in the hepatic veins, the latter vessels being injected from the former through the medium of the lobular venous plexuses of the portal vein.

Of the Red and Yellow Substances of FERREIN, *and of the Appearances produced in the Liver by Congestion.*—The structure of all the lobules is similar, and each lobule is of the same structure throughout; one part of a lobule is not more vascular than another; there is, therefore, no distinction of red and yellow substances in the liver; the red colour results from congestion only.

FERREIN first asserted the existence of two substances. "Sur la structure, il a trouvé dans chaque grain ou lobule du foye deux substances différentes; une qu'il appelle *corticale*, qui est extérieure, friable, et d'un rouge tirant sur le jaune; l'autre *médullaire*, ou intérieure, rouge, molle et pulpeuse, placée au centre de chaque grain, très-apparente dans plusieurs animaux, et souvent dans l'homme. Les conduits hépatiques traversent la substance corticale pour se rendre dans la substance médullaire, que M. FERREIN croit formée des extrémités pulpeuses de ces canaux‡." FERREIN's opinion respecting the existence of two substances has been very generally adopted by anatomists; some, however, have disagreed with him respecting their relative position to each other. Thus, AUTENRIETH says the yellow substance is medullary, and the red corti-

* LIEBERKÜHN used injection made of white wax, resin and Venice turpentine. "Sur les Moyens propres à découvrir la Construction des Viscères," Mémoires de l'Académie Royale des Sciences de Berlin, tom. iv. p. 28. 1748.

† Op. cit., p. 82.

‡ Mémoires de l'Académie Royale des Sciences, Histoire, 1733.

cal. Mappes, who was unacquainted with the lobular structure of the liver, which was known to Ferrein, says, "l'une de ces substances, qu'on peut appeler granulée, (médullaire, suivant Autenrieth,) forme des circonvolutions, tantôt semblables à celles des intestins, tantôt rameuses, plates et arrondies, de couleur jaune et assez denses, qui laissent entre elles des espaces arrondies d'un quart ou d'un travers de ligne de diamètre, ou des fissures oblongues le tout rempli par la seconde substance, laquelle est brune et moins serrée et qu'on peut appeler cellulo-vasculaire (corticale, suivant Autenrieth) *." To Meckel †, the view taken of the substances by Autenrieth and Mappes appears more just than that taken by Ferrein. Rudolphi says the terms cortical and medullary are not applicable to the substances, one not forming a bark for the other. The attention of pathologists has been lately directed in a particular manner to these supposed elements of the liver by MM. Boulland and Andral. Bichat, who thought it "impossible that all the substance of the liver is destined to secrete bile," was of opinion that the bile is secreted from arterial blood alone, and that the liver fulfils another function connected with the existence of the vena portæ ‡. On this subject M. Boulland remarks, "Si cette opinion est vraie, elle doit s'accorder avec l'anatomie du foie, c'est-à-dire, que si cet organe est chargé d'une fonction de plus que celle de la sécrétion de la bile, et que cette fonction ait rapport à la circulation sanguine, ou doit y trouver un appareil vasculaire spécialement destiné à ce dernier usage, en outre de l'appareil sécréteur de la bile." In speaking of the substances, the same pathologist says, "La substance jaune se présente sous forme de granulations saillantes, dont la figure, la couleur et l'arrangement doivent les faire regarder comme les grains sécréteurs de la bile, connus depuis long-temps sous la dénomination d'*acini*..... Ces granulations sont entourées de toutes parts par la substance brune, qui affecte par cela même diverses formes angulaires..... Cette substance, qui est toujours déprimée au-dessous du niveau des granulations jaunes, n'est pas seulement formée de tissu cellulaire, mais encore d'un lacis vasculaire, qui peut être comparé au tissu érectile §." M. Boulland con-

* Loc. cit.

† Manuel d'Anatomie, tom. iii. p. 452.

‡ Anatomie Générale, tom. ii. p. 260.

§ "Considérations sur un Point d'Anatomie Pathologique du Foie," Mémoires de la Société Médicale d'Émulation, tom. ix. p. 177.

siders that the *Cirrhose* of LAENNEC depends on a disassociation of the two elements; the appearances he has represented in fig. 1, and which, as he remarks, are frequently observed in connexion with disease of the heart, resemble some of those delineated by MÜLLER in Tab. XI., and arise from sanguineous and biliary congestion. M. ANDRAL coincides with M. BOULLAND in his opinion of the two elements, and says, "Isolées, ou réunies et combinées de plusieurs manières, les altérations de ces deux substances produisent les diverses états morbides du parenchyme hépatique*." M. ANDRAL considers the red substance as "éminemment vasculaire†,.... où se ramifie surtout le système capillaire de l'organe‡." Opinions opposed to those just cited are entertained by PORTAL, MÜLLER, and M. CRUVEILHIER. PORTAL merely observes, that "FERREIN avait avancé gratuitement que les glandes du foie étoient composées de deux substances, l'une corticale, et l'autre médullaire§." M. CRUVEILHIER, in his admirable work on pathological anatomy, says, "Il n'existe pas deux substances dans le foie, soit qu'on admette deux espèces de granulations, soit qu'on admette que chaque granulation est composée des deux substances à la fois. Ce qui a pu en imposer à cet égard, c'est que la partie centrale de chaque granulation répond au radicule biliaire, et conséquemment est souvent teinte en jaune, et que la partie excentrique répond à l'élément vasculaire, et conséquemment est plus rouge que la partie centrale‖." MÜLLER gives the following account of the two substances. "Diversam substantiam hepatis, utpote medullarem et corticalem, quæ per hepar totum undique obveniunt, qualem AUTENRIETH, BICHAT, CLOQUET, MAPPES atque etiam J. FR. MECKEL admittunt, equidem neque in historia evolutionis amphibiorum et avium, neque in hepate adultorum microscopicè observato, conspexi. Historia evolutionis hanc quæstionem evidentissime illustrat. Systema nimirum ductuum biliferorum in embryone amphibiorum et avium liberis finibus in superficie hepatis prominulis conspicuum. Sarmentula illa foliatim et paniculatim divaricata, colore e gilvo candido nitent, magnopere ab interstitiis sanguinolentis distincta. Hinc sane duplicis substantiæ species exoritur, quoniam circum duc-

* Clinique Médicale, 2de Edition, tom. iv. p. 178.
† Ibid., p. 176.
‡ Précis d'Anatomie Pathologique, tom. ii. p. 584.
§ Anatomie Médicale, tom. v. p. 277.
‖ Anatomie Pathologique du Corps Humain, Livr. xii. "Foie granuleux."

tuum biliferorum surculos et fines undique tela vasculosa subtilis sanguifera disponitur, ita ut interstitia ductuum biliferorum a tela conjunctiva expleantur, quæ et subtilissimis fere constat vasculorum sanguiferorum retibus, in quibus arteriæ et venulæ advehentes in revehentes venas transeunt. Atque hæc sola est utriusque substantiæ notio. Sed in omnibus organis glandulosis fere idem obvenit *."

My attention was first directed to the anatomy of the liver by the study of the admirable works of M. Andral. In the first organs I examined, I found the small branches of the hepatic veins ramifying exclusively in the red, and those of the portal vein in the yellow substance. I concluded that the liver was composed of two venous trees, a portal and an hepatic tree, the former having a cortex of yellow, the latter of red substance; and with M. Boulland I thought it probable that the red substance was the organ of the function imagined by Bichat. I next ascertained the lobular structure, and concluded with Ferrein that the red substance was medullary, and the yellow cortical. Subsequent dissections, in which I found branches of both the portal and hepatic veins ramifying in the red substance, tended to unsettle the opinions I had formed respecting the anatomy and physiology of the two substances; and these opinions were finally overturned by the examination of a liver in which I found the branches of the portal vein alone ramifying in the red, and those of the hepatic veins in the yellow substance. The only conclusion that could be drawn was, that the red colour resulted from congestion; that it was medullary, occupying the centre of each lobule, when the hepatic, and cortical, forming the circumference, when the portal vein, was congested. It occurred to me that the kidneys of birds having, like the liver, a double venous circulation, were equally subject to congestion, and would, like it, present an appearance of two substances. Dissection verified this conjecture; but the apparently two substances are red, one, however, being of a much deeper colour than the other. I have satisfied myself by repeated injections, by examination with the microscope, and by experiments on living animals, that the lobules are of the same structure throughout; that one portion of a lobule is not more vascular than another; that the acini of Malpighi, by contrast with the congested vessels, are even more apparent in the red than in the yellow

* Op. cit., p. 83.

substance; and that these supposed two substances are consequently identical in structure. That secreting biliary ducts are contained in the red as well as in the yellow substance, is proved by the relation given by M. Andral of a case of jaundice with "coloration insolite du foie." "Foie volumineux, pesant, très-dur, se déchirant difficilement, offrant une teinte générale d'un brun verdâtre. En l'examinant avec plus d'attention, on trouve que cette teinte n'est pas uniforme, et que le parenchyme du foie est formé, 1°. par un tissu d'un blanc verdâtre, disposé sous forme de lignes ou de plaques irrégulières (c'est le tissu blanc ordinaire hypertrophié); 2°. par un tissu d'un vert brun foncé, duquel dépend la couleur générale que présente le foie, et qui est l'analogue du tissu rouge ordinaire*." This was a case of vitiated biliary secretion, with general biliary and partial sanguineous congestion. The ordinarily yellow substance was of a greenish white colour, being congested with greenish bile only; the ordinarily red substance was of a deep brownish green, this colour evidently resulting from biliary and sanguineous congestion combined. I have met with more than one case of this kind; I have also seen cases of jaundice in which there was no biliary congestion of the liver, and the highest state of biliary congestion without jaundice. In attempting to estimate the causes of the various shades of colour observed in the liver, it is not sufficient to examine the cystic bile alone; the hepatic bile should be also examined, and it will be generally found, as in the above case, that these shades of colour depend either on biliary or sanguineous congestion alone, or on the various combinations of both.

Sanguineous congestion of the liver is either general or partial. In general congestion the whole liver is of a red colour (Plate XXI. fig. 6.), but the central portions of the lobules are usually of a deeper hue than the marginal portions. (Plate XXI. fig. 5.) Partial congestion is of two kinds, hepatic-venous and portal-venous congestion. Of the first kind there are two stages. In the first and most common stage, the hepatic veins, their intralobular branches and the central portions of the plexuses are congested. The congested substance is in small isolated patches of a red colour, and, occupying the centres of the lobules, it is medullary; the non-congested substance is of a yellowish white, yellow or greenish colour, according to the quantity and quality of the bile it contains:

* Clinique Médicale, 1ère Edition, tom. iv. p. 169.

it is continuous throughout the liver, and, forming the marginal portions of the lobules, is cortical. (Plate XXI. fig. 2.) This is passive congestion of the liver; it is the usual and natural state of the organ after death, and probably arises from its double venous circulation. In the second stage, the congestion extends through the plexuses to those branches of the portal vein situated in the interlobular fissures, but not to those in the spaces, which being larger than, and giving origin to, those in the fissures, are the last to be congested; when these vessels contain blood, the congestion is general, and the whole liver is red. In this second stage, the non-congested substance appears in isolated circular and ramous patches, in the centres of which the spaces and fissures are seen. (Plate XXI. fig. 3.) This is active congestion of the liver; it very commonly attends disease of the heart, and acute disease of the lungs or pleuræ: the liver is larger than usual in consequence of the quantity of blood it contains, and is frequently at the same time in a state of biliary congestion, which probably arises from the sanguineous congestion. Although in the first stage, the central portions of the plexuses, and in the second, the greater portion of each plexus and those branches of the portal vein occupying the fissures, are congested, and although the plexuses are formed by the portal vein; yet, as this form of congestion commences in the hepatic veins and extends towards the portal vein, and as it is necessary to distinguish this form from that commencing in the portal vein, the term of hepatic-venous congestion will not probably be deemed inapplicable to it. Portal-venous congestion is of very rare occurrence; I have seen it in children only. In this form, the congested substance never assumes the deep red colour which characterizes hepatic-venous congestion; the interlobular fissures and spaces and the marginal portions of the lobules are of a deeper colour than usual; the congested substance is continuous and cortical, the non-congested substance being medullary and occupying the centres of the lobules. (Plate XXI. fig. 4.) The second stage of hepatic-venous congestion, in which the congested substance appears, but is not, cortical, may be easily confounded with portal-venous congestion.

The physiological deductions arising out of the preceding anatomical facts are extremely simple. If it could be shown that two substances exist in the liver, it might be fairly presumed that this organ executes two functions; but each lobule being, in itself, a perfect gland, and of the same structure through-

out, each lobule, and consequently the whole liver, executes but one function, the secretion of bile*.

It has been shown that all the vasa vasorum of the liver are branches of the hepatic artery and portal vein; that branches of the portal vein arise in the coats of the hepatic veins themselves; and that the veins of the coats of the vessels constitute the hepatic origin of the portal vein. The arterial blood having circulated through the coats of the vessels, becomes venous, and is conveyed by the veins arising in the coats of the vessels into those branches of the portal vein which correspond to the vessels in the coats of which the veins arise: thus, from the coats of the vaginal ducts, veins and arteries they convey the blood into the vaginal veins; and from the coats of the interlobular ducts, veins and arteries into the interlobular veins. From the coats of the hepatic veins and inferior cava, the blood is conveyed into the interlobular portal veins. In the vaginal and interlobular veins, the blood conveyed from the coats of the vessels becomes mingled with the proper portal blood. This mixed blood is conveyed by the interlobular veins into the lobular venous plexuses, in which the lobular arteries probably terminate, after having nourished the secreting ducts. From the mixed blood circulating through the plexuses, the bile is secreted by the lobular or secreting biliary plexuses.

* M. Voisin (Nouvel Aperçu sur la Physiologie du Foie) has lately revived an old opinion respecting the physiology of the liver. The absorbents of the liver are, according to M. Voisin, of two kinds, the lymphatics and the chyliferous vessels: the former arise in the tissue of the liver and ramify on its surfaces; the latter are continuous with the chyliferous vessels of the intestines; they accompany the portal vein, and convey a portion of the chyle into the liver, in which, according to M. Voisin, it undergoes a certain change, and is conveyed from the liver into the receptaculum chyli by (as it would appear from M. Voisin's description) the same vessels. M. Voisin makes no mention of the valves of his chyliferous vessels, or of the impossibility of injecting these vessels, except by rupturing the valves, from the lesser omentum upwards towards the liver; but he asks, "S'il n'en était pas ainsi de l'origine et du trajet de ces vaisseaux lactés, d'où viendraient ceux qu'on remarque dans le foie, de quelle utilité lui seraient-ils?" If the abdomen of a dog be opened during the period of the absorption of the chyle, no part of this fluid will be found in the absorbents (the chyliferous vessels of M. Voisin), which leave the liver at the transverse fissure and descend, covered by the peritoneum of the right edge of the lesser omentum, to enter a lymphatic gland situated near the duodenum. If a ligature be placed on the vessels near the duodenum, the absorbents above the ligature will, in a few minutes, become turgid; if the ligature be loosened, the turgid vessels will soon resume their natural appearance. If the ligature be placed on the vessels near the transverse fissure, the absorbents below the ligature, being no longer supplied with fluid from the liver, will collapse and be no longer perceptible.

The blood which enters the liver by the hepatic artery fulfils three functions: it nourishes the liver; it supplies the excreting ducts with mucus; and, having performed these purposes, it becomes venous, enters the branches of the portal vein, and contributes to the secretion of the bile. The portal vein fulfils two functions; it conveys the blood from the artery, and the mixed blood to the coats of the excreting ducts. It has been called the *vena arteriosa*, because it ramifies like an artery, and conveys blood for secretion; but it is an arterial vein in another sense, being a vein to the hepatic artery, and an artery to the hepatic vein. The hepatic veins convey the blood from the lobular venous plexuses into the vena cava inferior.

Ferrein was evidently well acquainted with the hepatic circulation; it is to be regretted that his "Mémoire sur la Structure et les Vaisseaux du Foye" was not published. The following account of the vessels is given from his description of them. "A' l'égard des vaisseaux sanguins, il a observé que les divisions et les subdivisions de la veine-porte donnent deux sortes de rameaux, les uns veineux et les autres artériels: il nomme rameaux artériels ceux qui sont connus par leur fonction de porter le sang de la veine-porte dans le foye: il a découvert les veineux, et ceux-ci reçoivent le sang de l'artère hépatique, et le conduisent dans les rameaux artériels de la veine-porte, de ceux-ci dans la substance médullaire des lobules, et de-là dans les branches de la veine-cave*." It does not appear that Walter ascertained the termination of any of the branches of the artery; he supposed that some branches of this vessel pour arterial blood into the portal vein; he says, "Extremitates ultimæ arteriarum in hepate evanescunt, ita, ut nonnullæ earum, partim in cellulosa hepatis interna terminentur, hinc illam nutriant, partim sub forma fasciculorum florum, vel potius in directione fere stellari in reliquam hepatis sustantiam se dispergentes, ramulos venæ portarum perforent, in eorum cavum sese aperiant, ibique tandem liquidum quoddam ad bilem idoneum magis perficiendam secernunt: reliqui rami, ramos venæ cavæ et ductus hepatici elegantissimo reticulo vasculoso, irretiunt†." Of the functions of the artery, the same anatomist says, "Officium ergo arteriæ hepaticæ duplex erit, vel substantiam cellulosam

* Mémoires de l'Académie Royale des Sciences, Histoire, 1733.

† De Hepate, p. 96, in Annotationes Academicæ, Berolini 1786.

membranasque vasorum hepatis nutrire, vel partem aliquam bili necessariam secernere et in ipsam venam portarum deponere *."

M. SIMON† concluded from his interesting and ably conducted experiments, that the bile is secreted from the portal blood alone; and Mr. PHILLIPS arrived at the same conclusion from the issue of two experiments in which he tied the hepatic artery, the details of which are in the possession of the Royal Society. From the issue of three experiments in which the portal vein was tied, and in in which bile was secreted, and from the cases related by Mr. ABERNETHY and Mr. LAWRENCE, Mr. PHILLIPS concluded that bile might be secreted from arterial blood alone‡. I have shown that the bile is secreted from venous blood alone, this blood being composed of the two streams which enter the liver by the portal vein and hepatic artery; and from the anatomical details into which I have entered, it is evident that bile will be secreted, but in different quantity, whether the vein or the artery be tied, and from venous blood in both cases. The quantity of arterial blood conveyed to the liver is so small, and death so soon follows the ligature of the vein, that in experiments on rabbits and kittens, in which I tied the vein, I cannot say that bile was secreted.

It appears to have been satisfactorily ascertained by TIEDEMANN and GMELIN§, and by M. VOISIN‖, that the bile is a purely excrementitious fluid, stimulating the intestinal canal, but having no influence on the formation of the chyle. The lungs separate from venous blood an excrementitious matter in a gaseous form; the liver, extracting from venous blood an excrementitious fluid, may be considered as the abdominal lung.

A few eminent physiologists, founding their opinion on false anatomical data, on the cases related by Mr. ABERNETHY and Mr. LAWRENCE, and on the absence of the hepatic-portal vein in the invertebrated animals, in which the liver is supplied with arterial blood only, maintain that the bile is secreted from arterial blood. Since the conclusions contained in this paper respecting the

* De Hepate, p. 105, in Annotationes Academicæ, Berolini 1786.

† Nouveau Bulletin des Sciences par la Société Philomatique de Paris, 1825. Edinburgh Journal of Medical Science, No. 1. p. 229. Birds are better adapted for these experiments than the mammiferous animals, the portal vein in the former animals communicating freely with the posterior cava. M. SIMON performed his experiments on pigeons.

‡ London Medical Gazette, June 29, 1833. § Recherches sur la Digestion, 2de Partie, p. 38.

‖ Op. cit.

physiology of the liver were first submitted to the Society, I have been enabled, through the kindness of Mr. STANLEY, to examine the liver of the child in which Mr. ABERNETHY found that the portal vein terminated in the inferior cava. Mr. ABERNETHY's account of the case is contained in the Philosophical Transactions for 1793. Mr. GREEN, in his anatomical lectures, had always described this case, as presenting less anomaly than was commonly supposed. He considered that the umbilical vein ramified through the liver, that the artery probably terminated in it, and that the vein and not the artery conveyed the blood to the secreting part of the liver. Sir CHARLES BELL also, in speaking of this case, makes the following highly interesting observations: "We may observe on this case, that it does not prove the bile to be, in the natural economy, secreted by the arteries and not by the vena portæ; for the artery here was unusually large, so that it performed a function in this instance which it does not usually perform. Had the artery been of the usual size, we might then have concluded that the vena portæ was distributed to the liver to serve some lesser use in the economy of the system, and that it did not secrete the bile. The liver, it is said, was of the ordinary size. Now as the bulk of the liver is, in its natural state, made up of the dilated veins, it is some proof of what I should imagine had taken place here, that by some provision of the vessels, the arterial blood had been diffused, and the celerity of its motion checked previous to its ultimate distribution. Nay, it may have opened into the branches of veins answering to the extremities of the vena portæ. I conclude, that this singular and interesting case may strengthen the opinion which some have entertained, that the extreme branches of the hepatic artery pour blood into the extremities of the vena portæ previous to this formation of the bile by these veins; but it still leaves us with the general conclusion, that the peculiarities in the distribution of the vena portæ are a provision for the secretion of the bile, and that the branch of the aortic system, the hepatic artery, is otherwise necessary to the support of the function of the liver *."

I examined the liver of this child, which had not been examined by Mr. ABERNETHY, in the presence of Mr. STANLEY, Mr. MAYO, and several other gentlemen, in the Museum of Saint Bartholomew's Hospital. Mr. ABERNETHY had injected the arteries with red, and the hepatic veins with yellow size. As had

* The Anatomy and Physiology of the Human Body, vol. iii. p. 330.

been happily conjectured by Mr. Green and Sir Charles Bell, we found the open and uninjected ramifications of the umbilical vein (the hepatic-portal vein) accompanying, as usual, the branches of the hepatic artery and duct. By making sections of portal canals, we found the arteries, as Mr. Abernethy had described them, much larger than usual. In ordinary cases one principal artery is found in each canal; in this case two, and in some places three arteries of equal calibre were found in each canal. The branches of the umbilical or portal vein, which are usually so much larger than those of the artery, were found, on the surfaces of sections of this liver, to be, as nearly as we could judge, equal in calibre to the united dimensions of the two or three arteries which accompanied each branch of the vein. Bichat, in support of his opinion that the bile is secreted from arterial blood, says, "On dit que le volume du foie est considérable, à proportion de l'artère hépatique: cela est vrai; mais ce n'est pas au volume de ce viscère qu'il faut comparer celui de cette artère pour savoir si elle fournit les matériaux de la sécrétion, puisque nous avons vu qu'il est impossible que toute sa substance soit destinée à séparer la bile. C'est avec les conduits biliaires et leur réservoir qu'il faut établir la comparaison: or, cette artère est exactement proportionée à ces conduits; il y a entre eux à-peu-près même rapport qu'entre la rénale et l'uretère; au contaire, les conduits biliaires sont bien manifestement disproportionnés à la veine porte *." Bichat's opinion, and the argument here offered in support of it, are completely refuted by the dissection of the liver in this case. The branches of the duct were much smaller than those of the artery; in one canal, in which there were three arteries of equal dimensions, the duct was of about half the size of one artery. (Plate XXI. fig. 6.) This case, therefore, does not establish an analogy between the biliary organs of the vertebrated and invertebrated animals; but, on the contrary, it shows that the class of monstrosities to which it belongs, forms a much slighter deviation from the ordinary vertebrated type than was imagined†. Nor does it militate against the conclusions maintained in this paper upon the physiology of the liver; although, as Mr. Mayo observed, it cannot be supposed that the arterial blood, in its passage through the vasa vasorum into the branches of the umbilical vein, underwent the usual change into venous blood; and it

* Anatomie Générale, tom. ii. p. 260.

† Meckel, Manuel d'Anatomie, tom. ii. p. 588. I. Geoffroy Saint-Hilaire, Histoire des Anomalies, tom. i. p. 456.

was still, he contended, arterial blood, though less pure in character, which was conveyed through venous canals into the secreting part of the liver.

A case, similar to Mr. Abernethy's, which was met with by the late Mr. Wilson, is mentioned by Mr. Lawrence * and Dr. Monro †. The history of this case was lately read at a Meeting at the College of Physicians, by Dr. Wilson, to whom I am indebted for the following particulars. The subject was a girl, thirteen years of age, who met with her death from an injury of the head. The vena portæ terminated in the inferior cava; there were two splenic veins, one of which entered the portal vein, and the other the cava near the point where it becomes surrounded by the liver. Mr. Wilson says, "I could trace no vein passing into the liver at the cavity of the portæ; the remains of the umbilical vein were impervious; I traced them to the entrance of the portæ, *and now regret that I had not traced them sufficiently far to see with what set of vessels they were united*.....The hepatic artery," Mr. Wilson continues, "came off in a distinct trunk from the aorta, and ran directly to the liver: it was much larger than it usually is, but not so large as the trunk of the vena portarum; it entered the liver as usual. The gall-bladder had nothing remarkable in its appearance: it was of a size proportioned to that of the liver, and contained more than half an ounce of bright yellow fluid, similar in appearance to the bile; it was not, however, submitted to any other test but that of sight." The umbilical vein in this case was obliterated as far as it was traced by Mr. Wilson; but, as in Mr. Abernethy's case, its hepatic branches were doubtlessly open, and received the blood from the artery, which they conveyed to the coats of the secreting ducts. No portion of the liver was preserved ‡.

While engaged in the examination of the natural structure of the Liver, I have not been inattentive to the changes produced in it by disease; and, with the permission of the Society, I propose submitting to its consideration a paper on the Morbid Anatomy of this organ.

* Medico-Chirurgical Transactions, vol. v. p. 174.

† Elements of Anatomy, vol. ii. p. 564. 1825.

‡ In the case related by Lieutaud after Bauhin (Historia Anatomico-Medica), the liver and spleen, it is said, were wanting, the portal vein terminating in the inferior cava. The case related by Huber (Programma sistens Observationes aliquot Anatomicas), which, in the Index to Sandifort's Thesaurus Dissertationum, is entitled "Diaphragmatis Habitus singularis," was, as Meckel and Rudolphi observe, probably a case in which the hepatic veins perforated the diaphragm previously to entering the cava, and not an unusual termination of the portal vein, as has been supposed by some anatomists.

Explanation of the PLATES.

PLATE XX.

Fig. 1. A. An hepatic vein.

B. Lobules arranged around the intralobular branches of the hepatic veins, as they are frequently seen at the posterior part of the concave surface of the liver. This arrangement is more distinctly seen in the liver of the sheep than in the human liver. These lobules are parallel to the surface.

Fig. 2. Displays the three sets of branches constituting the hepatic veins.

A, A, A. The intralobular hepatic veins.

B, B. The sublobular-hepatic veins, in which the intralobular veins terminate.

C, C. Hepatic trunks, in which no intralobular veins terminate.

D. The mouths of intralobular veins opening into the sublobular veins.

E. The mouths of small sublobular veins.

F. The mouths of large sublobular veins.

Fig. 3. A longitudinal section of sublobular-hepatic veins, with lobules arranged around them.

A, A. Sublobular-hepatic veins.

B, B. Longitudinal sections of lobules, presenting a foliated appearance.

C, C. The bases of the lobules resting on the sublobular veins, and forming the canals containing them. The bases of the lobules are connected to the sublobular veins by the intralobular veins.

D. The external or capsular surfaces of the lobules.

E, E. The intralobular veins running through the centres of the lobules.

F. The projecting processes of the lobules, with their veins terminating in the central vein. The intralobular veins correspond in form with the lobules, the number of smaller veins being equal to the number of processes.

G. The mouths of intralobular veins opening into the sublobular vein.

Fig. 4. A. An oblique section of a sublobular-hepatic vein.

B, C, D, E, F, G. As in the preceding figure.

H. The bases of other lobules seen through the coats of the vein, and forming the canal in which the vein is contained. The centre of the base of each lobule is occupied by an intralobular vein.

I. The interlobular fissures seen through the coats of the vein.

Fig. 5. Longitudinal sections of an internal, and of two superficial lobules.

A. A sublobular-hepatic vein.

B. The convex surface of the liver.

C. An internal lobule, in which the smaller veins are seen commencing about the middle of the processes of the lobule, the substance of which completely surrounds them. The intralobular vein is also surrounded, except at the base of the lobule, where it makes its exit to terminate in the sublobular vein.

D. Two superficial lobules.

E. An intralobular vein commencing at the surface of the liver.

F, F. Two smaller veins, commencing at the surface and terminating in

G. An intralobular vein commencing at the surface. The superficial lobules are perforated by the intralobular veins, and when compared with the internal lobules, appear as if their upper portions had been removed.

H, H. The substance of the liver, formed by other lobules.

Fig. 6. A. A transverse section of a lobule.

B. The divided central intralobular vein.

C. The smaller veins, terminating in the central vein.

Fig. 7. A. A transverse section of a double lobule.

B, B. The smaller veins, terminating in

C. The divided central veins.

Plate XXI.

Fig. 1. A. Angular lobules in a state of anæmia, as they appear on the external surface of the liver.

B. The interlobular spaces containing the larger interlobular branches of the hepatic duct, portal vein and hepatic artery.

C. The interlobular fissures, in which the smaller interlobular branches of the hepatic duct, portal vein and hepatic artery ramify.

D. Intralobular veins, occupying the centres of the lobules.

E. Smaller veins, terminating in the central veins.

Fig. 2. A. Rounded lobules in the first stage of hepatic-venous congestion, as they appear on the external surface of the liver.

B & C. The interlobular spaces and fissures; they are larger than those represented in the preceding figure, and contain more cellular tissue.

D. The congested intralobular veins.

E. Appearances produced by congestion of the intralobular hepatic veins, and of the central portions of the lobular venous plexuses, and constituting the medullary substance of FERREIN, the cortical substance of AUTENRIETH, the red substance of MM. BOULLAND, ANDRAL and other anatomists, and the cellulo-vascular substance of MAPPES. These appearances may be produced by injecting the central portions of the plexuses from the hepatic veins.

F. The non-congested marginal portions of the lobules, constituting the cortical substance of FERREIN, the medullary substance of AUTENRIETH, the yellow substance of MM. BOULLAND and ANDRAL, and the granular substance of MAPPES.

Fig. 3. A. Lobules in the second stage of hepatic-venous congestion, as they appear on the external surface of the liver.

B & C. Interlobular spaces and fissures.

D. The congested intralobular veins.

E. Appearances produced by more extensive congestion of the lobular venous plexuses. It will be remarked that in this, as in the preceding, figure, the intralobular veins and the central portions of the lobules are congested, but that, in this figure, the congestion is not confined to the centres of the lobules; that it extends to their margins and to those branches of the portal vein which ramify in the interlobular fissures; the congested substance is

consequently continuous, and the non-congested substance is in isolated patches. As the congestion extends from the hepatic to the portal vein, and as those branches of the portal vein contained in the fissures are smaller than those contained in the spaces, those in the fissures are congested before those in the spaces; the fissures are, therefore, in many parts rendered obscure, in consequence of the congested state of the smaller interlobular portal veins contained in them, and of the corresponding marginal portions of the lobules: the congestion not having extended to the veins in the spaces, those portions of the lobules immediately surrounding them are not congested. This is the red or medullary substance of Ferrein, now appearing cortical; in the preceding figure it appeared medullary; in this, it is continuous throughout the liver; in the preceding figure it was in isolated patches. This appearance also may be produced by injecting the plexuses from the hepatic veins.

F. Non-congested portions of lobules, much resembling, in some parts, transverse sections, and, in other parts, longitudinal sections of single lobules. These apparently whole bodies are composed of the non-congested, opposite, marginal portions of three or four contiguous lobules, the congestion not having extended to the portal veins ramifying in the spaces and fissures which are seen between the different portions of which they are formed. They are of a yellowish white or yellow colour, according to the quantity and quality of the bile they contain. These are the bodies represented by Müller, Tab. XI. fig. 11, by M. Boulland, Plate II. fig. 1. and by Dr. Hope, figg. 104 and 105. This is the non-congested, or yellow, substance now appearing medullary, and in isolated patches; in the preceding figure it appeared cortical and continuous. This is the nutmeg liver of pathologists, the hypertrophy of the red substance of M. Andral.

Fig. 4. A. The lobules as they appear on the surface in a state of portal-venous congestion.

B. The interlobular spaces and fissures; they are of a darker colour than those represented in fig. 2, in consequence of the congested state of the interlobular branches of the portal vein.

C. The intralobular hepatic veins; containing no blood, they are smaller, and of a lighter colour than those represented in figg. 2 and 3.

D. The central portions of the lobules in a state of anæmia. This is the yellow or non-congested substance appearing medullary, and arising from non-congestion of the intralobular veins, and of the central portions of the lobular venous plexuses.

E. The marginal portions of the lobules in a congested state. This is the congested substance appearing cortical and continuous, as in the preceding figure, but arising from a different cause,—from congestion of the interlobular branches of the portal vein and of the marginal portions of the lobules. This appearance may be produced by injecting the marginal portions of the lobular venous plexuses from the portal vein.

Fig. 5. A transverse section of a large portal canal and its vessels. The lobules are in a state of general congestion, their central portions being more congested than their marginal portions.

A. Superficial lobules forming the parietes of the canal. They are similar to those of the external surface, being perforated by their intralobular veins. Some are observed in which these veins do not extend to the capsular surfaces of the lobules, this appearance depending on the direction in which the incision is made.

B. Internal lobules not entering into the formation of the parietes of the canal. In these lobules the intralobular veins are completely surrounded by the substance.

C. A transverse section of a portal vein.

D. Vaginal branches arising from the vein, and dividing into interlobular branches, which enter the interlobular spaces.

E. A transverse section of an hepatic duct.

F. A vaginal branch arising from the duct, and dividing into interlobular branches which enter the spaces.

G. The artery.

H. A vaginal branch arising from the artery, and dividing into interlobular branches which enter the spaces.

I. Three interlobular vessels, a duct, vein and artery entering each interlobular space.

J. The vaginal plexus, formed by the vaginal branches of the duct, vein and artery. The internal surface of the plexus is in contact with the large vessels; its external surface is in contact with the parietes of the canal. The vessels forming the plexus ramify in cellular tissue, which, with the vessels, constitutes the vaginal portion of Glisson's capsule. The capsule in these larger canals completely surrounds the three vessels.

Fig. 6. Represents a transverse section of a small portal canal and its vessels. The lobules are in a state of general congestion.

a. The portal vein, a great portion of which is in apposition with the interlobular spaces on the parietes of the canal.

b. The interlobular branches arising from the trunk and entering the spaces, with the branches of the duct and artery, without ramifying in the canal. On this side the vein resembles an hepatic vein in having no vaginal branches.

c. Two vaginal branches arising from the vein, and dividing into interlobular branches on that side of the canal on which the vein is separated from the spaces by the duct and artery. On this side, the vein, giving off vaginal branches, and being separated from the parietes of the canal by the capsule and vessels, resembles the larger portal veins.

d. The duct giving off vaginal branches.

e. The artery giving off vaginal branches.

f. Three vessels, a duct, vein and artery, entering each interlobular space on the surface of the canal.

Plate XXII.

Fig. 1. A longitudinal section of a small portal vein and canal; the lobules are in a state of anæmia.

A, A. Portions of the portal canals, from which the vein has been removed. The parietes are composed of lobules, similar to those of the external surface of the liver, separated from each other by fissures and spaces.

B. The portal vein; the lobules and fissures are seen through its coats.

C. Mouths of interlobular veins, which, arising immediately from the portal vein, enter the spaces without forming a plexus. This portion of the vein, giving off no vaginal branches, and consequently having no capsule, resembles in these respects an hepatic vein.

D. Two larger orifices. These are the mouths of vaginal veins which enter the canal, and divide into two, three, or more interlobular branches.

E, E. The orifices of small portal veins, which enter other canals.

F. Vaginal branches arising from the vein and forming a plexus on that side of the canal occupied by the duct and artery. These branches are seen dividing into branches, which enter the spaces covered by the duct and artery.

G. The hepatic duct, giving off vaginal branches.

H. The hepatic artery, giving off vaginal branches.

Fig. 2. A longitudinal section of an hepatic vein. The lobules are in the first stage of hepatic-venous congestion.

A, A, A. Sublobular-hepatic veins, terminating in

B. An hepatic trunk. No intralobular veins terminate in this vein; its coats are not transparent; the hepatic-venous canal containing it is lined by a prolongation of the proper capsule.

C. The capsular surfaces of the lobules forming the canal, in which the venous trunk is contained. The veins of these lobules terminate in a neighbouring sublobular vein.

D, D. The parietes of the hepatic-venous canals, a portion of the vein having been removed.

E, E. The orifices of the intralobular veins, which enter the sublobular veins from the centres of the bases of the lobules forming the parietes of the canal containing the veins. Each orifice is situated in the centre of the congested portion (the red substance of Ferrein) of each lobule.

F. Longitudinal sections of lobules, the intralobular veins of which are seen terminating in the sublobular vein.

G. The orifices of intralobular veins less closely arranged than at E, E.

H. The capsular surfaces of lobules, which, with the bases of other lobules, form these canals.

I. The parietes of the canal containing this vein are formed by the bases alone of lobules.

Fig. 3. A. An hepatic duct.

B, B. The transverse branches of the duct.

C, C. Branches which ramify in the direction of the trunk.

D, D. Recurrent branches.

E. Smaller branches arising at the angles formed by the preceding branches.

Fig. 4. A longitudinal section of a portal canal, with an hepatic duct and its vaginal branches ramifying on the parietes of the canal. The lobules are angular and in a state of anæmia.

A, B, C, D, E. As in the preceding figure.

f. A vaginal duct leaving the canal and dividing into interlobular branches.

G, G. Ducts entering smaller portal canals.

Plate XXIII.

Fig. 1. Represents the internal surface of a small hepatic duct, with its follicles aranged in two longitudinal lines.

Fig. 2. An hepatic vein of the *Seal* laid open, and showing the circular fibres of which its external coat is composed.

Fig. 3. Represents the interlobular ducts entering the lobules, and forming the lobular biliary plexuses.

a. Two lobules.

b, b, b. Interlobular ducts.

c, c, c. The interlobular cellular tissue.

d, d. The external portions of the lobular biliary plexuses injected.

e, e. The intralobular branches of the hepatic vein.

f, f. The uninjected central portions of the lobules.

No such view of the ducts as that represented in this figure can be obtained in the liver. The interlobular ducts are, in the figure, seen anastomosing with each other: I have never seen these anastomoses, but I have seen the anastomoses of the ducts in the left lateral ligament, and, from the results of experiments related in this paper, I believe the interlobular ducts anastomose. I have never injected the lobular biliary plexuses to the extent represented in the figure.

Fig. 4. Represents the biliary ducts ramifying in the left lateral ligament of the liver.

a. The left lateral ligament of the liver.

b. The posterior edge of the left lobe of the liver.

c. The loose edge of the ligament.

d. That edge of the ligament which is connected to the diaphragm.

e, e. Biliary ducts emerging from the liver and ascending to ramify in the ligament.

f. Arches formed by the ducts towards the upper part of the ligament.

g. The plexuses formed by the minute ducts.

Fig. 5. Representing the interlobular branches of the portal vein, the lobular venous plexuses, and the intralobular branches of the hepatic veins of three lobules.

a, a, a. The interlobular veins contained in the spaces.

b, b, b. The interlobular veins which occupy the fissures, and which, with the veins in the spaces, form venous circles around the lobules. This is the appearance which the venous circles present when

examined with a common magnifying glass; they are, however, formed by numerous, and not by single, branches, as represented in the figure.

c, *c*, *c*. The lobular venous plexuses, the branches of which, communicating with each other by intermediate vessels, terminate in the intralobular veins. The circular and ovoid spaces, seen between the branches of the plexuses, are occupied by portions of the biliary plexuses, constituting the acini of MALPIGHI.

d, *d*, *d*. The intralobular branches of the hepatic veins, in which the vessels of the plexuses terminate.

Fig. 6. A transverse section of a portal canal, showing the relative dimensions of the vessels in the liver of the child, in which the portal vein terminated in the inferior cava.

a. The umbilical, or hepatic-portal vein.

b. Three arteries contained in the same canal.

c. The duct.

a. An hepatic vein.

XXX. *Some Observations on the Economy of Molluscous Animals, and on the Structure of their Shells.* By JOHN EDWARD GRAY, *Esq., F.R.S., &c.*

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1. *First Formation of Shells.*

THE shells of Mollusca appear to be coeval with the first formation of the animal: they may be observed covering the embryo on its first development in the egg, even before it has acquired its proper shape or any of its internal organs. The accurate SWAMMERDAM observed them in the eggs of several of the garden and pond snails. His observations have been recently verified and extended by PFEIFFER, on many species of land and fresh-water Mollusca; and I have myself observed the same fact in the eggs of several animals belonging to the different orders of marine shells: there is reason, therefore, to believe that this circumstance is general throughout the class. These observations are most easily made on the embryo of the fresh-water shells, such as the *Lymnææ*, *Physæ*, *Ancyli*, and *Bithyniæ*, the eggs of these animals being covered with a transparent coat; while the viviparous Mollusca, and especially the *Littorinæ*, *Paludinæ*, and *Cyclades* *, offer the additional advantage of exhibiting the embryos of their animals in all the different states of development at the same time.

The cephalopodous Mollusca form no exception; their bone, composed of

* Between the laminæ of the branchiæ of the *Anodontes* and *Uniones* are found small cordate, bivalve bodies, which have been considered as their young; but they differ so much in external form and internal structure from the adults, that many excellent naturalists, and especially Professor JACOBSON, of Copenhagen, have considered them as parasites. It is, however, remarkable that they are found in abundance in almost every specimen, and PFEIFFER has apparently proved that they are the young, he having found them constituting the umbones of very minute *Uniones*. I have searched for them in vain in this situation; perhaps because I have never been so fortunate as to discover specimens of the young shell so small as those figured by this author. If PFEIFFER should prove to be correct, this remarkable change of form and structure will be the only approach towards a metamorphosis that has been hitherto observed in this class of animals.

two or three calcareous plates, being found fully developed in the egg of the Cuttle-fish some time before the young animal is hatched.

These observations are directly at variance with the theory maintained by the late Sir Everard Home*, viz., that the shell of the Vermes Testacea is formed after the animal has quited the egg; and as regards the Cuttle-fish, they are opposed to the remark, made by the Baron Cuvier, that the young Cuttle-fish, when first hatched, has only a cartilaginous plate like the *Loligo*.

The shell when first observed on the embryo (even of the animals of spiral shells) forms a short, blunt, more or less curved, subcylindrical cone, covering the hinder part of its body: as the organization of the embryo becomes developed, and the hinder part of the body extended, the shell increases in size, till the body and shell together occupy nearly the whole of the egg. While inclosed in the egg, the embryo shells are generally of a pale horn colour, and destitute of markings: when, therefore, they remain attached to the apex of the spire of adult shells, they may be easily distinguished by their appearance from the part formed after their exclusion; and as, in such cases, they offer some characters of importance, it has been proposed to designate them by the name of the Nucleus of the shell.

The effect of the atmosphere on the shell is almost instantaneous: in some young *Helices* and in a species of *Voluta* in my collection, the very first line of calcareous matter deposited after their exclusion from the egg is marked nearly as the adult shells of the species.

The nucleus may be generally distinguished from the perfect shell, by the rapid enlargement of its whorls, by its extreme tenuity, by its want of colour, and by the great obtuseness of that part which is earliest formed and constitutes the extremity of its first volution. It is necessary to pay attention to these particulars, inasmuch as the nuclei of some large species have been mistaken for full-grown shells, and vicé versâ. Thus the *Murex decollatus* of Pennant is the just-hatched shell of the *Fusus despectus*; Risso's genus *Orbitina* is established on the nuclei of two land shells; and the genus *Vitrina* was regarded by Montagu as the nucleus of the Common Snail. In some instances the first half-whorl of the nucleus, (the part first formed on the embryo,) instead of being regularly curved, is bent across the tip of the other

* Philosophical Transactions, 1817, p. 229.

whorls, as in the *Pyramidellæ*, or placed in an oblique position with regard to the succeeding one, as in *Voluta papillosa* and some other species.

The nuclei of many shells of different genera have not the same characters as their parent shells; thus the nucleus of the Tritons has a short anterior nick, instead of an elongated canal, and is very like a minute Buccinum. Some retain the generic but not the specific character of the group to which they belong; thus the nuclei of the Volutes in general have the pillar slightly plaited, but the young of *Voluta musica* has only two or three plaits on its pillar, while the adult has many.

The nucleus forms the original apex of the valves of all shells whatever may be their form, and frequently remains attached to them during all their periods of growth; this is particularly the case with the Volutes, in which, from its large size and rounded shape, it has been called the Nipple. It is also conspicuous on most of the species of *Dolium* and on some *Fusi*, among the univalves; and on the apices of the valves of the *Cyclades*, and *Chamæ*, among the bivalves.

This part of the shell has not received the attention that it deserves. It is largest in those shells the animals of which are viviparous; and is consequently very distinct in the *Volutæ*, *Paludinæ* and *Cyclades*. In the oviparous species it agrees in size with the egg of the animal; thus *Achatina octona*, which has an egg nearly equal in dimensions to the mouth of the shell, and *Bulimus ovatus* and *B. bicarinatus*, which have large eggs, have large nuclei, the magnitude of the nucleus in general rendering the top of the spire blunt. Some shells on the contrary, those, for instance, of the genus *Stylina* generally, and of the *Pupa purpurea*, have a very long, slender, acute, turreted nucleus, but the form and size of the eggs are in these cases unknown.

The nucleus is found on examination to consist of two very distinct parts or coats, the outer of which is membranaceous or horny, and called the Periostracum, and the inner hard and calcareous, and constitutes the Shell.

These two coats may be observed in all the stages of the shell: they are generally very thin in the nucleus, and the outer one is rarely distinctly visible in that state; but it is to be clearly seen (covered with five or more bands of hair-like processes) in the very young *Paludinæ*. In such shells as are enveloped in the mantles of their animals, as the *Dolabellæ*, *Aplysiæ* and *Bullææ*, the outer coat or periostracum is very thin; it is, however, to be found in all shells,

and may also be observed on the shelly plates of the Cirrhipedes. In some instances, as in the Cowries and Melons, the outer coat of the shell is covered in the adult age with a deposition of shelly matter, which entirely conceals it from view. A few shells, as for example those of *Loligo* and *Aplysia*, contain so little calcareous matter, as to appear to be formed entirely of periostracum.

2. *The external Form of Shells, and their Variations.*

Each valve of a shell, according to the manner in which it is first formed and subsequently increases, is a more or less depressed or lengthened cone. The apex of this cone is always oblique: in all the shells with which I am acquainted, it is excentric; and in most of the univalve shells, whether they be simply conical, involute or spiral, it is directed from the head of the animal towards the hinder part. The only exception, as far as I know, to this rule, occurs in the genera *Patella* and *Lottia*, in which the apex is directed from the hinder part towards the head; and this is the more remarkable, as in the Chitons, the animal of which so much resembles that of *Patella*, each of the valves takes the usual direction. The similarity of direction in the two genera above named is still more curious, as their animals bear scarcely any resemblance to each other.

The nucleus of the bone of the Cuttle-fish and of the *Loligo*, is placed in the same direction; for it is the conical process at the end of the bone of the Cuttle-fish (called *Beloptera*, when found in the fossil state,) which must be regarded as the nucleus of these shells. If, however, the relative position of the animal of the Nautilus, the anatomy of which has been admirably described by Mr. Owen, be correctly assigned by that author, with respect to its shell, it must offer a similar anomaly with the genera *Patella* and *Lottia*. The shells of the Pteropodes, as for example *Hyalæa*, *Cleodora* and *Vaginella*, take the same direction as the other univalves; and it was this circumstance that gave rise to the supposition that M. de Blainville, in his figure of the animal of *Cymbulia*, had placed it in the shell in the wrong position. The numerous specimens which are now in European cabinets have proved the accuracy of this supposition.

In bivalve shells the apex of each valve is always placed on or near the dorsal or hinge margin, varying its position on this part in the different groups.

Thus, in the *Pectines* and other suborbicular shells, which having a very large subcentral posterior adductor muscle, were called by Lamarck *Monomyaires*, the apex is generally in or near the centre; while in most of the other genera it is placed more or less towards the anterior extremity of this margin, and is sometimes incurved. In some of these shells the apex is spirally twisted, and the spire becomes more developed as they increase in size. Now this could not take place if the valves remained inseparably united together at the same part of the dorsal margin; but it is provided for by the hinge of the shell being gradually moved backwards on the edge of the valves, the ligament separating in front of the hinge into two parts, one of which diverges along each of the umbones, and forms a spiral groove down the suture of the whorls. In *Isocardia* the umbones seldom make more than half a turn, but in one specimen of *Chama* in my collection they have made an entire revolution, and in another a revolution and a half. The valves of these shells being unequal, the spiral part of the lower or attached valve is produced into an elongated cone, while in the other it is depressed, and simply marked with a spiral groove, like that of an operculum.

In most bivalves the hinge margin, which is deposited by a part of the mantle extended behind and between the teeth, increases in size much more slowly than the other margins of the shell; but in some free shells, such as the *Arcæ*, this part increases nearly as rapidly as the rest, and the umbones thus become separated from each other by a lozenge-shaped disk. In others which attach themselves to foreign bodies, as the *Spondyli* and *Ostreæ*, the hinge margin of the attached valve only enlarges, forming a triangular flat-topped process, while that of the upper valve is scarcely increased in size. Thus the cavity of the shell, as the growth proceeds, gradually retreats from the part by which the attachment first took place.

The direction followed by the whorls in passing down the axis derives its origin from that which the shell takes in the egg; and is probably dependent upon the direction in which the embryo rotated whilst inclosed therein. In most shells they turn from left to right, and the mouth is on the right side of the axis, when the shell is in its natural position; but in others, which are called sinistral or reversed, the whorls are twisted in the contrary direction. The sinistral direction appears to be constant in many species, especially

among the air-breathing Mollusca; in all belonging to the genus *Clausilia*, among the land ones; and in all the *Physæ*, *Planorbes* and *Ancyli*, among those which inhabit fresh water. But besides these entire genera, the shells of which are invariably sinistral, there are numerous species of *Bulimus*, *Partula*, *Pupa*, and *Chondrus*, that are uniformly so twisted; and there are even some that are sometimes twisted in one direction and sometimes in the other, as *Bulimus Lyonettianus*, *B. aureus*, &c. Among the marine shells the sinistral direction is much more rare, although there are a few species, such as *Fusus sinistrorsus* of Deshayes, *F. contrarius* and *F. sinistratus* of Lamarck, and some species of *Cerithia*, which are constantly so contorted. The *Pyrula perversa* is as often found twisted in one direction as in the other, and its shells have even been considered as different species according to the direction of their whorls. Of other marine species liable to the same variation, I have observed *Buccinum undatum*, which is not uncommonly found reversed; *Turbinella napus*, the reversed variety of which is much sought after by the Chinese; *Oliva oryza*, *Nassa reticulata* and *N. Thersites*; but there are some genera in which I do not recollect to have noticed its occurrence, as, for example, the *Cyprææ* and *Ovulæ*.

A bivalve shell is composed of a dextral and a sinistral valve, united together by a ligament. When the two valves are separated, and spread out on a table with the umbones above, and the front end towards the observer, the valve to the right (the left when on the animal and in its usual walking position,) resembles a dextral, and that to the left a sinistral, very depressed spiral shell. This is well illustrated by comparing the left valve of an *Isocardia* with a *Concholepas*. In some very rare instances these shells also are reversed, but the fact is not easily observed, except in the unequal-valved kinds. There were formerly in the Tankerville collection two specimens of *Lucina Childreni*, in one of which the right valve was a dextral shell, in opposition to the general structure. A much more remarkable variation is to be observed in some of those bivalve shells, whose under valve is attached to foreign bodies; thus, for example, most of the *Chamæ* are attached by their left valve, but some species, such as *Chama Lazarus*, are frequently attached by their right valve, under which circumstance the teeth proper to the left and usually attached valve are transferred to the right, and vice versâ.

The equality or inequality of the valves of bivalves appears to be dependent on the habitual position of the animal. Thus all the genera whose animals bore perpendicular holes in rocks, like the *Pholades*; or bury themselves in the mud of rivers, as the *Uniones*; or in the sand of the sea-coast, as the *Cardia*; or walk freely about on the shores, as the *Veneres*; or are attached by a byssus which passes out of a gape formed by the inflection of the margins of both valves, as the *Tridacnæ*, *Saxicavæ* and some *Arcæ*, have equivalve shells: whilst on the other hand, all those Mollusca whose shells are immediately attached by the outside of one of their valves, as the *Etheriæ*, *Ostreæ*, *Spondyli*, *Himnites* and *Chamæ*; or of which the animals are attached by a byssus passing through a groove near the umbo of one of the valves only, as the *Pectines*, *Aviculæ*, *Pedà* and *Anomiæ*; or which lie free on the surface of one of their valves, as the *Ostreæ*, *Anatinæ*, and some of the *Arcæ*, are more or less inequivalve. In those inequivalve shells which are attached by the intervention of a byssus, this substance passes out through a groove in the right valve, which is the smallest; whilst, on the other hand, in those that are immediately attached by the outside of the shell, the right valve is affixed, and the left is the smallest, sometimes indeed so disproportionately as to appear like a lid to the other. It is only in the families *Ostreidæ* and *Anatinidæ*, which have unequal valves, that there are found some genera entirely free, and others which are immediately attached. The free inequivalve shells offer some curious anomalies in the relative size of their valves; nearly all the *Anatinidæ*, as *Anatina*, *Periploma* and *Magdala*, having the left valve the smaller, as have also the genera *Corbula* and *Sphænia* of the family *Myidæ*; whilst the other two genera of that family, *Mya* and *Pandora*, and *Lyonia* among the *Anatinidæ*, have the right valve the smallest.

In the *Terebratulæ* and Brachiopodous Mollusca in general, the valves being applied to the dorsal and ventral, instead of the lateral, surfaces of the animal, their lateral halves are analogous in situation to the right and left valves of other bivalves, and the byssus by which the animals are attached passing through a hole in the centre of the dorsal valve, the sides of the shell are equal. The dorsal or perforated valve is superior and convex in all the genera of this order, with the exception of *Discina*, in which, the usual position of the animal being reversed, it is inferior and flattened.

In all shells, the young of which I have had an opportunity of observing, the nucleus or shell of the animal when first hatched is regular. The irregularity in the form of adult shells appears to depend on their becoming attached to foreign substances, for it is only among attached shells that any irregularity of form is found, and even these are perfectly regular so long as they continue free. This explains why irregular shells are more rare among the univalves than among the bivalves, as not more than three or four genera of the former ever become attached. Good examples of shells which are irregular when full grown, although regular in their very young state, may be seen in the genera *Ostrea*, *Chama*, *Hinnites*, *Magilus*, and *Vermetus*. The very young shell of *Chama arcinella*, which closely resembles in form a minute *Petricola*, is frequently found persistent and constituting the apex of the umbones of adult specimens; and so regular is its form, that I have little doubt, were a conchologist to meet with a very young free specimen among the sand of the West Indian coasts, that he would refer it either to the latter genus, or to the genus *Cardita*. In like manner the very young shell of *Hinnites pusio*, when persistent in the umbones of the adult, cannot be distinguished from a free regular *Pecten*.

Many univalves exhibit the same phenomenon: the young *Spiroglyphus* and *Magilus*, as will hereafter be described, are quite regular so long as they remain free; and the apices of all the *Vermeti* and *Siliquariæ* show that they also are regular in their youth. The apex of the former has indeed been mistaken for a regular spiral shell, and described as a *Turritella* by Lamarck and by Dr. Turton.

Some land shells (for it is only in such shells that I have observed it,) offer a very curious anomaly in their form: they are quite regular in their young state, but change the direction of their last whorls as they approach maturity, and in some cases even reverse the position of the mouth. A remarkable instance of this change of direction occurs in a rather common Brazilian snail, which is transversely striated in its young state, and exactly resembles a common umbilicated snail; but acquires when adult a smooth last whorl much larger than the others, and pressed towards the side next the mouth, by which means the axis is bent out of the line, and the umbilicus is compressed and closed. This obliquity in the form of its whorls gives the shell the

appearance of having been slightly crushed, from which circumstance it has been called by Baron Férussac *Helix contusa*. A similar departure from the regular form is found, in even a greater degree of development, in a minute species from the same country, named *Helix deformis* (Wood's Supplement, tab. 7. fig. 40.); and may also be seen in a slight degree in the *Helix concamerata* of Wood's Supplement, tab. 7. fig. 21. The last whorl of *Bulimus Lyonettianus* is compressed on the side opposite to the mouth, and produced into an acute angle, which gives the shell a very anomalous appearance. A somewhat analogous deformity, but not so much developed, may also be observed in *Helix Auris Leporis*. This kind of variation is, however, not confined to the inoperculated land shells, for the *Cyclostoma compressum*, figured by Mr. Wood in his Supplement, tab. 6. fig. 42, differs from all others of the genus in its last whorl being compressed, although not in so great a degree as in the *Bulimus Lyonettianus*; and in the *Cyclostoma tortum* (*Turbo tortus* of Wood's Supplement, tab. 6. fig. 32.) the last whorl is slightly pressed on one side like that of *Helix contusa*, the mouth being produced in front, and nearly in a line with the axis.

But the most remarkable of these anomalies occurs in the genus *Anastomus*, where the mouth of the young shell occupies its ordinary situation in front of the whorls, the animal in this early stage doubtless crawling in the usual manner, with the spire of the shell uppermost; but as it approaches maturity, the end of the last whorl is curved upwards, and the mouth of the perfect shell is applied to the upper edge of the last whorl but one, with the opening directed towards the tip of the spire, in such a manner that, in walking, the animal must crawl with the tip of the spire downwards, and thus completely reverse the position of its shell. A similarly formed shell has been discovered in the fossil state, and named *Strophostoma*, and this, from the roundness of its mouth, has been supposed to belong to the family of *Cyclostomidæ*.

The axis of most spiral shells is perfectly straight, but the species of some few genera, such as *Eulima* and *Stylifer*, are very liable to have it more or less curved or twisted. And this is not the only point of resemblance between these two genera, both having the same polished surface and similar varices on the spire; but they differ in the degree of solidity of their shells. The *Styliferi* live buried in the substance of Star-fish, which may perhaps account for their inflections: the habits of the *Eulimæ* are unknown.

The growth of other spiral univalve shells appears never to be thrown out of its proper course, except by some accident, such as the interruption caused by the occasional attachment of a foreign body, or by a fracture. I have a *Fusus virgo* and a *F. colosseus*, which are thus bent; and there are two specimens of the common Whelk in the British Museum, the spires of which are very much elongated, the elongation having evidently been caused by a fracture in their very young state. One of the latter has been described as a distinct species, under the name of *Buccinum acuminatum*. Sometimes, after the occurrence of such an accident to a spiral shell, the form or sculpture of the whorls is entirely altered: they often become ventricose and smooth, instead of remaining thick and ribbed, as in the common state of the shell; and this change of form has even occasioned shells under such circumstances to be regarded as distinct species. As an instance of this I may refer to *Cingula alba* of Dr. Fleming, founded on specimens of *Turbo parvus* of Montagu, which had been injured in their growth. In Mr. Turner's collection there is a specimen of *Terebra maculata*, which had sustained an injury when about an inch and a half in length: the whorls beyond this injury are rounded and elevated near the suture, and are destitute of the posterior groove. In this specimen the colouring also is altered, for instead of being spotted, the irregular volutions are marked only with two narrow posterior spiral bands.

A distortion or change of form, caused by a fracture or other accident, is sometimes overcome, as the animal increases in size and recovers its strength. Thus a specimen of *Strombus bituberculatus* in my collection, which had met with an accident in its young state, has the five upper whorls sharply keeled and nodulous, as in the ordinary state of the shell, but the volutions formed after the accident turn more obliquely down the axis, and thus their anterior part becomes more exposed, leaving a deep narrow groove on the suture. The first half-whorl that succeeds the fracture is rounded and distinctly tubercular; after which the shell continues rounded, but quite smooth for a whorl and a half; when it again becomes slightly tubercular, and at length keeled and tubercular, the last whorl exactly resembling the last whorl of the normal shell. The collection of Mr. Lincolne of Highbury contains a specimen of *Cassis rufa* in a very similar state.

The shape of attached shells depends greatly on the form of the bodies to

which they are applied; and this is a circumstance that has been generally overlooked by conchologists. It strongly affects most shells that are immediately and permanently attached, such as the *Chamæ* and *Ostreæ*, which completely assume the form of the substances on which they grow. Thus the *Chamæ* and *Spondyli* attached to the plane surface of mother-of-pearl shells have always a flat side, whilst those which are adherent to coral and to other uneven surfaces are variously and irregularly shaped. The Oysters which are attached to the branches of mangrove trees have a central convex rib, modelled on the shape of the branch, from which the plaits of the shell radiate; while the specimens of the same species fixed to the trunk are destitute of any such peculiarity. In the collection of Mr. Adamson of Newcastle there is a curious specimen of a common Oyster found in the Frith of Forth attached to a species of *Pecten*; on the latter there also grew three corallines, surrounding the Oyster, which have formed in its circumference three deep notches, giving it the form of an ace of clubs. The same changes may be observed to take place in the *Anomiæ*, which are attached by the intervention of a ligamentous band; thus the species called *Anomia squamula* is founded on young shells of the common *A. ephippium* attached to flat surfaces; whilst *A. cymbiformis* is characterized from small specimens of the same shell attached to the cylindrical spines of sea eggs, or to the stems of sea weeds.

A similar influence is also observable in such free univalve shells as have a widely expanded mouth, and an animal provided with a large foot, by means of which they remain for a considerable length of time adherent in the same situation. When a *Patella* or a *Crepidula* has attached itself to the flat surface of a rock or the leaf of a large *Fucus*, the base of its shell is flat, and its mouth roundish; when it adheres to a concave surface, such as the cavity of an old shell, the base becomes flattened, and convex internally; and when it fixes itself on the rounded stalk of a *Fucus*, the sides become compressed so as in some measure to clasp the stem, and the lateral portions of the base project beyond the front and hinder parts, to such an extent that when placed on a flat surface it rocks backwards and forwards. Several nominal species of these and allied genera depend on variations in the shape of the shell caused by the adhesion of the animal to surfaces of different forms; thus the *Patella pellucida* of Montagu is synonymous with the *P. cærulea* of the same author, the former having

been founded on specimens taken from the stalk, and the latter on individuals obtained from the flattened frond of the *Fucus* on which the species usually takes up its abode: it is indeed by no means rare to find specimens in which the animal has moved from one of these positions to the other, and in such cases the apex of the shell represents *P. cærulea* and the base *P. pellucida*, or vice versâ. The same change takes place with regard to *P. miniata* and *P. compressa*. I have in my collection a specimen of this latter shell which is *P. miniata* at the top, it having in its youth lived on the frond of a large Cape *Fucus*: it afterwards removed to the stem, and became compressed, and consequently is in this part the *P. compressa*; but by some accident it was again induced to change its situation, and, removing to a flat surface, the edge of the mouth expanded, and it became a second time *P. miniata*, or perhaps what may be called by some authors *P. saccharina*, as this also appears to be a conical variety of the same species. Lamarck has described a similar specimen; and Mr. Sowerby, in his Genera of Shells, has figured an example of this species, showing the two states. In like manner the *Crepidula porcellana*, when applied to a flat surface, has an expanded base and a flattened inner lip; but when adherent to a convex body, such as the stem of a sea-weed, or (as frequently happens) to the back of another shell of the same species, the animal being pressed into the cavity, the inner lip becomes concave, and the sides of the aperture are contracted: in this state the shell is called by most authors *C. fornicata*.

When the shells of this family are adherent to irregular surfaces, they adapt their margins to the inequalities with which they meet. I have several specimens from the coast of Devonshire, having one or more processes on their sides, which fitted into holes in the rock to which I found them attached; and such changes are the more remarkable, as some specimens are seen constantly moving from place to place, whilst others appear to remain for a long time fixed in one spot, and even those that are thus stationary in the young state constantly elevate the margins of their shells when the tide is low. I have also a specimen of *Siphonaria gigas* exhibiting in a great degree a similar adaptation of its edges to the form of the rock on which it grew.

The substances to which attached shells become adherent, besides altering their general form, often change the character of their surfaces; thus, when fixed to ribbed shells, like the *Pectines*, *Cardia*, &c., they are frequently

variously ribbed, a circumstance which often takes place in the common *Anomiæ*; and if attached to a *Dolium*, as in a specimen in the collection belonging to Mrs. Mauger, they even exhibit on their own surface the alternate broad and narrow ribs of that shell. In specimens of *Crepidula adunca* attached to *Trochus doliarius*, (and inhabiting the same locality, they are not unfrequently so attached,) the convex part of the former is marked with the ribs of the latter. Shells which are ribbed from this cause are, however, easily distinguishable from those which are naturally ribbed, the ribs in the former generally extending across or along the shell, and not radiating from its apex or nucleus, as in all shells the natural character of which is to be ribbed. In those which adhere to ribbed shells by the foot of their animal (as in most of the univalves), and are therefore capable of being moved from place to place, the young animal may have lived on a smooth surface, and have had a smooth shell; and may have moved, during its growth, to a ribbed body, producing ribs on the later formed part of its shell, or vice versâ. In a specimen of *Crepidula adunca*, for example, in the British Museum, the upper half of the shell is smooth, and the lower half ribbed; and I have seen specimens, on the contrary, in which the apex was ribbed and the base smooth.. This change of form has, however, misled some conchologists, for Dr. Bronn, of Heidelberg, has founded a genus under the name of *Brocchia*, on a specimen of *Capulus*, which had acquired a ribbed surface in consequence of having been attached to a *Pecten* or to some other radiated shell.

These alterations of form and surface are always most distinct in univalves and in the upper valve of bivalves. In the latter case, the edges of the upper valve being produced beyond those of the under, they are immediately moulded on the surface of the substance to which the shell is attached, whilst the under valve simply covers it over. This is well illustrated in the unique specimen of *Hinnites gigantea* in the collection of the British Museum, which must have been attached to some marine body having a *Serpula* growing upon it. There is merely an irregular convexity in the inner part of the under valve, but on the outer surface of the free valve is to be observed a representation of the whole form, and of almost the entire surface of the *Serpula*, in consequence of the edge of that valve, during each deposition of shelly matter, having rested on the worm-shell. In the collection of Mr. Lincolne is a specimen of an

Oyster which, having been attached to a plank covered by a number of *Balani* and *Serpulæ*, has the upper valve marked with prominences, exactly agreeing in shape with the substances concealed beneath the under one. The edges of the valves of Barnacles being very closely affixed to the surface of the substances to which they are attached, it appears that they not only assume the form of the larger prominences, such as the ribs and spines of a shell, but also the most minute differences of its surface. A Barnacle in my collection, which had been fixed to a Scollop (*Pecten suborbicularis*), has not only the ribs of the latter marked across its valves, but the whole surface of the prominent part of the valves is covered in addition with minute rugosities, produced by the small projecting scales which cover the surface of the ribs of the *Pecten*, whilst the articulating portion of the valves is smooth, as in the common state of the species. In another similarly ribbed specimen the articulating portions are also ribbed like the rest of the valves; and in a third, which was found on a piece of roughly planed and loosely textured wood, the surface of the valves bears an exact resemblance to the grain of the wood on which the specimen was attached.

The thickness, the roughness, and the smoothness of the surfaces of shells appear to depend, in a great measure, on the stillness or agitated state of the water which they inhabit. The species of our own coast afford abundant instances of this: the shells of *Buccinum undatum* and *B. striatum* of Pennant have no other difference than that the one has been formed in rough water, and is consequently thick, solid and heavy; and the other in the still water of harbours, where it becomes light, smooth, and often coloured. In the same way the specimens of *Purpura Lapillus*, which inhabit sheltered situations, are covered with small arched scales, whilst those found in exposed places are thick and rugose. Lamarck, not being aware of this circumstance, considered the specimens in the first state as a distinct species, which he named *Purpura imbricata*. The English shells of the genus *Pinna* (and doubtless the foreign ones also,) offer the same variations, which have given rise to similar subdivisions of species. Shells which have branching or expanded varices, like the *Murices*, are also much influenced by these circumstances; and hence many mere varieties, arising from local causes, have been considered as distinct species. Thus *Murex angulifer* is merely a *Murex ramosus* with

simple varices; and *Murex erinaceus*, *M. torosus*, *M. subcarinatus*, *M. cinguliferus*, *M. Tarentinus* and *M. polygonus*, are all varieties of one species. *Murex Magellanicus*, when found in smooth water, is covered with large acute foliaceous expansions; but the same shell living in rough seas is without any such expansions, and only cancellately ribbed. In such situations it seldom grows to a large size; but when it does so, it becomes very solid, and loses almost all appearance of cancellation. *Triton maculosus* is very widely spread over the ocean in different temperatures and different kinds of seas; it consequently offers a multitude of varieties both in size and surface, all gradually passing into each other, and most probably produced by the operation of the foregoing causes. Indeed, a vast number of merely nominal species have been formed from the habit, too prevalent among conchologists, of describing from single specimens, or even from several individuals brought from the same locality, which would never have been considered as distinct had collectors kept in their cabinets a series of specimens found under different circumstances, and studied, on the coasts where they are found, the variations which shells undergo.

Those shells which are attached to rocks, either immediately by their outer surface, or by the intervention of a beard, are most acted on by these causes: thus the *Anomiæ* found in protected places are thin and transparent, while those which inhabit exposed situations are thick and nearly as opake as the shell of an oyster; and the under valves of the *Craniæ* which are affixed to the branches of coral are very thick and solid, while those that adhere to the *Pinnæ* and other flat shells are so thin as to have been overlooked by conchologists, who have repeatedly described their upper valve as a species of *Patella*.

Boring shells are greatly influenced in regard to their size, thickness and form by the hardness or softness of the rock in which they are found: thus the specimens of *Pholas dactylus* found in the soft rock of Salcombe, are large and thin, and are covered with beautiful, regular, arched scales; while those found in the hard rock are small, irregular, thick, with a very wide anterior gape and large dorsal valves, and closely wrinkled externally, but almost or entirely destitute of scales: and the *Saxicavæ*, found in hard limestone, are often curved and otherwise distorted, in order to avoid the harder parts of the rock during the process of boring.

Land shells are much influenced, as regards their size, by the temperature, altitude, and abundance of food, of the country in which they are found. Specimens of *Helix arbustorum* from the Swiss Alps, are not one half the size of those of the neighbourhood of London; the shells of *Helix nemoralis* and *H. hortensis*, found in the last-named locality, are not above two thirds the size of those which occur in Portugal and in the South of France; and there is so much difference in size between individuals of *Bulimus rosaceus* found on the coast and on the mountains of Chili, that the latter have been described as a distinct species under the name of *Bulimus Chilensis*. There would be no difficulty in multiplying examples of the same kind.

It is not so easy to determine the influence of climate on marine shells, although there is little doubt, from the great differences of size observable between specimens of the same species, brought from different localities, that it actually exerts considerable power. Indeed, I have been enabled to mark this difference in some of the shells found on our own coast. The specimens of *Littorina petræa* found on rocks with a southern exposure near Torquay, are larger than almost any others which I have met with in England; but the largest of this species that I have seen, occur on the part of the Breakwater at Plymouth next the sea, where they are much exposed to the sun. The latter are twice the size of any that I found on the northern face of that magnificent structure.

The colouring of many shells evidently depends on the degree of exposure to light, air, heat, and the action of the waves to which they may have been subjected. Thus, among the *Patellæ* and *Crepidulæ*, those which are attached to the stems of *Fuci* or other round bodies, and are thus exposed on all sides, are of a dull colour, or nearly colourless. This is well exhibited in the specimen of *Patella miniata* before referred to, which had changed its place of attachment twice during its growth; the two portions of the shell formed while the animal was affixed to a flat substance being white, beautifully varied with bright red, (the general colour of *P. miniata*), whilst the central portion of the shell is of a dirty yellow, with a few indistinct, reddish dots, like the ordinary specimens of *P. compressa* *. In like manner *P. pellucida* when obtained from the stems

* Such exposed shells are very rarely brightly coloured; but a specimen of *Patella compressa* formerly in the collection of the late Earl of Tankerville, but now in that of Mr. Lincolne, is coloured nearly as brightly as *P. miniata*.

of *Fuci* is of a pale horn colour, whilst the same shell, on the leaves, is of a beautiful purple with longitudinal pale blue lines. The thinnest specimens of a species are generally the best coloured. The light certainly exerts considerable influence on the strength of colour, even in marine shells; and it appears to be owing to its modifying power that many *Nassæ*, *Buccina*, *Naticæ*, *Cyprææ*, and other littoral shells, have the back part much darker than the rest. This is particularly the case with *Nassa glans*, *Natica castanea*, and several Cowries, as *Cypræa stolida*, *C. errones*, and *C. caurica*, which have always an irregular bright red spot on the back of the body volution.

The colour of shells is generally disposed in rays, streaks, or bands, arising from the nucleus and extending to the circumference; in the spiral shells the lines of colouring consequently follow the direction of the whorls. The rays vary greatly in size; they are sometimes interrupted, and they generally become wider as the shell grows larger.

These coloured bands are evidently deposited by glands placed on the margin of the mantle. Sometimes the action of the glands is interrupted, and the bands are broken. In a few shells this suspension of the action of the glands takes place at regular and very short intervals, in which case there is formed a chain-like band, as in *Marginella catenata*, certain Cones, and some other shells. In the *Volutæ*, *Olivæ*, *Coni* and some *Cassides*, the colouring often forms angular lines, so disposed, that the glands which deposit it seem to have receded from each other, and then again contracted together. Sometimes, as in *Oliva tessellata*, for example, these lines are broken into spots; but even in this species some specimens exhibit the spots united into angular lines.

In general the colour is situated on the outer coat of the shell. It is often deposited on the inner side of the outer layer, as in *Strombus bituberculatus*, and sometimes extends a little into the outer part of the middle layer; but I do not recollect to have ever seen it pervade the whole thickness of this coat. This circumstance leads me to believe that the colouring matter is generally deposited by the glands immediately after the deposition of the calcareous particles on the periostracum, and during the formation of the outer coat which, as will be seen hereafter, is always deposited before the two inner ones.

This situation of the colouring matter explains the reason why many shells,

such as the Olives and Cones, are darker when their outer coat is removed; as is particularly the case with *Oliva utriculus*, which is often sold in that state as a different shell. There is reason to believe that Lamarck was deceived by a specimen which had been so mutilated, and which he described as a distinct species, under the name of *O. harpiformis*.

The belts across the whorls of the *Olivæ* and *Ancillariæ* have the coloured matter deposited on their inner surface. In a few shells, the *Oliva porphyria* for example, some of the more distinct coloured lines even form raised ridges on the outer surface; and in some others the inner layer is darker than the outer. Thus in *Oliva tessellata* and *O. lineolata*, and in some Cowries, the inner layer is purple; in *O. ispidula*, brown; in *Turbo chrysostomus* and *T. Nicobaricus*, bright golden; in *Capulus Hungaricus*, in *Strombus gigas*, and in many others, pink: but it is generally much paler, and in the greater number of shells white or colourless.

Some brown shells, such as the Volutes, become white when touched with a hot iron: there was formerly in the Museum at Paris a specimen of a Melon, marked in this manner with close series of white spots. The purple colour of some shells is also changed under a similar treatment to dusky red; and it is by this process that the red spots are formed on the polished muscle-shells and uncoated Nutmeg Cowries, which are so abundant in the shops. A very curious effect is produced by ink on some purple shells, which I have seen only in individuals of that colour. On the receipt of the Cracherode collection of shells at the British Museum, my uncle, Dr. Gray, wrote on each of them with a pen and ink the number of the catalogue and the name of the species. In many instances, although the ink has been washed off, the name and number are still distinctly visible, forming an evenly raised letter as broad as the ink line, and slightly interrupted, as if by bubbles, in a few places. This is particularly visible in the specimen of *Solen diphos*, No. 186. in that collection. The effect, however, is not produced in all shells of this colour, nor even in some of the same natural genus which were written upon at the same time; but as I have observed it in a few other purple shells, and as I have not met with it in any of a different colour, I am inclined to think that the nature of the colouring matter may have some share in its production.

3. *The Structure of Shells.*

Shells exhibit, when examined, two very distinct kinds of structure: in the one case the calcareous particles of which they are formed are crystallized, in the other they are granular. These differences in structure correspond with differences in their chemical character, the shells in which the lime is crystallized appearing to contain less animal matter than the others. The primary division of shells according to their structure consequently agrees with the division proposed by Mr. Hatchett, in his paper on their chemical composition; the porcellaneous shells of that distinguished chemist being crystalline, and the nacreous granular.

Shells of the crystalline structure are themselves of two very distinct kinds; the crystals being rhombic in some, and prismatic in others.

Those of the rhombic crystalline structure exhibit, when broken, three distinct layers of calcareous matter. On examining fragments of most of the spiral univalves, there will be observed on two of the fractured sides of the cubic pieces into which they generally break, flat surfaces on the inner and outer edges, separated from each other by a shelving portion in the centre; and on the two intermediate broken sides shelving external and internal edges, connected by a flat central portion; these differences of surface being produced by the different position of the crystals of the different layers.

Each of the three layers thus rendered obvious is composed of very thin laminæ, placed side by side, as high as the thickness of the plate and perpendicular to its surface. When these laminæ are minutely examined, they will be found marked with obscure oblique lines; in the direction of which they separate, when broken, into long narrow rhombic crystals. The lines of cleavage in the succeeding laminæ are placed in contrary directions, so that when two of these plates united are examined under the microscope, the lines of cleavage appear to cross each other at right angles, whilst those of the alternate laminæ follow the same direction.

The laminæ of the outer and inner plates are always directed from the apex of the cone of which the shell is formed towards its mouth; in the spiral shells they consequently follow the direction of the spire. On the contrary, the laminæ of the plate situated between the other two, form concentric rings round

the cone parallel with its base, and cross at right angles those of the inner and outer layer. This decussation of the laminæ of the plates, and of the crystals of the laminæ themselves, adds considerably to the strength of the shell, and accounts for the great difficulty that is found in breaking many shells of this structure, more especially the Cones and Olives, in which, however, nearly the whole of the strength resides in the outer whorl and in the spire.

A good illustration of this structure may be obtained by examining with a pocket-glass the fractured edge of a Cone, Olive, or other spiral shell, in which the *extremities* of the laminæ of the outer and inner plates, and the *sides* of those of the central layer, or the converse, will be observed, according to the direction of the fracture; the extremities of the laminæ showing the angles of the crystals, while their sides, when closely examined, will often exhibit the crystalline flakes. In order to observe the lines of cleavage, the best mode of proceeding is to bruise part of a shell with a hammer, and to examine the fragments moistened under a microscope, until one is discovered which exhibits two laminæ in conjunction. The plates and their structure are also well seen in the polished surfaces of shells which have been slit or ground down to exhibit the internal structure of their cavity. The relative thickness of the three plates varies in different species; but as far as I have yet examined, the central plate is generally rather the thickest, and the outer one the thinnest. The Italian cameo cutters appear to be aware of this circumstance, and avail themselves of it in cutting the cameos, the ground being always formed of the innermost layer of the three, which is also generally the most transparent.

The layers increase in thickness from their inner to their outer edge, each of them being formed by successive depositions of thin coats of animal and calcareous matter on its inner surface until it acquires the proper thickness for the shell, the outermost edge of which is very thin, and has during the progress of the growth little calcareous matter, but gradually passes into the periostracum.

This *accumulation* of calcareous particles, deposited at various times and nevertheless forming the same crystals, is well illustrated in the prismatic crystalline shells. These are also evidently formed of several layers, which in some instances, as in the *Pinnæ*, are distinctly separate from each other: if, however, the shell be cracked transversely to its layers, the crystals will be found conti-

nued across the line which separates them. An analogous structure exists in some minerals, the Hæmatite for instance, the balls of which appear to be formed of separate concentric coats, but nevertheless when they are broken exhibit the crystals radiating from the centre to the circumference without interruption.

The plates of which the rhombic crystalline shells are formed are deposited in succession, each gradually increasing in thickness as the shell enlarges, and undergoing no variation in this respect after the deposition of the succeeding coat has commenced. That the coats are deposited in regular succession, may be seen by examining the lip of any shell which has been taken whilst the animal was increasing its size. At this period the lip will be found gradually shelving and becoming thinner from the inner to the outer edge, the innermost part being formed of three, the next of two, and the outer and thinnest part, which is always the first formed, of only a single layer. This is best seen by making a section of the lip of a Strombus or a Cone along one of the spiral grooves, in which, if the polished edges be examined, the layers will be distinctly seen. When the animal is about to make its periodical stoppage of growth, the second, and afterwards the innermost layer is deposited up to the edge of the mouth, which is thus completed.

In the *Olivæ*, *Ancillariæ*, and some *Volutæ*, which have, at all periods of their growth, a polished surface, (now known to be caused by their shell being more or less immersed in the large foot of the animal,) the outer layer, although equally crystalline, is very thin. It is harder and much more compact than the others, and between it and the central layer is deposited an opake, white, powdery film, which often causes it to break off in splintery flakes, while the rest of the shell separates into fragments, generally more or less cubical, their shape depending, doubtless, on the rectangular disposition of the laminæ of which the plates are formed.

Some Olives, as *Oliva utriculus*, *O. undatella*, and *O. acuminata*, have an additional band, in structure and hardness resembling the outer coat, forming a belt over the latter, across the front of the whorls; and some *Ancillariæ*, as *Ancillaria marginata*, have also a similar belt placed on the back of the volutions.

When the animals of many of the shells of this structure arrive at their full

size, or when they form the successive mouths of their shells at their periodical stoppages of growth, they deposit a considerable number of layers of shelly matter, either on the lip or on the pillar: these layers are formed of laminæ disposed in the same manner as those of the inner layer of the body of the shell, and, indeed, may be considered as repetitions of this part.

The animals of some genera, as for instance *Cypræa*, *Ovula*, *Erato*, and *Marginella*, deposit, at the same period, on the outside of their shells an additional coat covering the lip and back, which may also be considered as a continuation of the inner layer, since it agrees with this layer in the position of the laminæ: it changes its character, however, on becoming external, being harder, more compact, and often differently coloured. In all these cases the sides of the mantle of the adult animal are expanded into wing-like processes, which are reflected over the shell, and deposit the additional layer. In the *Cyprææ*, *Erato*, and *Ovula*, in which the lobes of the mantle are large and nearly meet, there is left a differently coloured line at the place of their junction, which, on account of the left lobe of the mantle being usually the largest, is generally situated on the right side of the back, and is called the dorsal line: this line is not observed on the *Marginellæ*, the lobes of the mantle being in them less developed, and leaving a broad uncovered space on the back.

It is probable that the polished coat of the *Struthiolaria oblita* is formed in the same manner, but the animal of this shell has not been examined. From the reflected form of the lip, however, in other species of that genus, and from the edges of the mantle in the other genera of the family of *Strombidæ* (to which *Struthiolaria* evidently belongs,) becoming developed when the animal attains its full growth, as is proved by the expansion of the lips of the *Strombi* and the lobed form of those of the *Pterocerææ* and *Rostellariæ*, it is easy to suppose that its lobes may even become completely reflected.

The species of *Cymbium*, when fully grown, or under particular circumstances, are often covered externally with an additional glazed coat, which is apparently deposited by the foot, as the animals of these shells do not appear to be provided with large lobes to their mantle. This coat being deposited over the periostracum, is liable to be broken off.

There is deposited on the sides, and more especially in the posterior part, of the cavities of the upper whorls of many of the spiral univalves, a transparent

calcareous concretion, which lines, and more or less fills up the cavity. This deposit may be observed lining the cavity of the upper whorls of *Mitra episcopalis*, *Triton pileare*, *Cassis glauca*, *Voluta hebræa*, and several other shells. In some, which have an elongated acute spire, as in the various species of *Fasciolaria*, and in the turreted shells, such as the *Terebræ*, *Cerithia* and *Turritellæ*, it entirely fills the cavity of the tips, which, from their small size and original thinness, would otherwise have been liable to be broken. Its deposition is not confined to adult shells, for I have observed it filling the cavity of the upper volutions, and lining the succeeding ones, in a slit specimen of a young *Strombus gigas* in the possession of Mrs. J. P. Atkins, to whom I take this opportunity of expressing my thanks for her kindness and liberality in allowing me to examine the numerous dissected shells in her collection.

In those Volutes which retain the nucleus (or that form which the shell has when first hatched,) that part, which was originally very thin and brittle, is speedily filled up with the deposit in question. In fact, all shells whose spires are exposed, and, being thin in their young state, would be liable to be broken off by the action of the sea, have that part strengthened by the internal deposition of calcareous matter.

The distinction between these and the decollated shells, such as *Bulimus decollatus*, *Cerithium decollatum*, &c., is, that in the latter, the animal, instead of lining the upper whorls with an internal coat, suddenly withdraws its body from them and forms behind its extremity a concave septum; and the vital communication between the body and the apex of the shell being thus cut off, the latter part decays, in the manner of a dead shell, and falls off in particles*.

The greatest development of the deposit mentioned above is to be observed in the genus *Magilus*, in which the young shell is very thin, shaped like a *Purpura* and of a crystalline texture; but when the animal has attained its full size, and has formed for itself a lodgement in a coral, the greater part of the cavity of its shell is filled with a glassy substance, leaving only a small conical space for the reception of its body: layer after layer of this substance are then deposited in rapid succession, in order to keep the body of the animal on a

* M. de Blainville refers the decollation of the spire to the inner surface of the cavity of the shell becoming filled with a very brittle glassy deposit.

level with the top of the growing coral in which it is buried, until its shell is almost lost in the quantity of glassy matter subsequently formed.

The shells of the prismatic crystalline structure exhibit, when broken, a quantity of short fibres perpendicular to the surface: when examined, these are found to be mostly hexagonal prisms, with a few smaller polyhedral prisms interposed. This structure, which has been repeatedly described, is to be observed in the tube of the large *Teredo* from Sumatra, in the vitreous deposit of *Magilus*, and in many bivalves, especially those which belong to the families of *Mytilidæ* and *Aviculidæ*, as the *Pinnæ*, Mother-of-pearl shells, &c.; and it may likewise often be seen in fossil shells, such as the *Inoceramus*, fragments of which, exhibiting this structure, are frequently found imbedded in flints.

On the other hand, shells of the concretionary structure exhibit, when broken, a nearly uniform texture: they separate, when heated, into numerous thicker or thinner laminæ; and when digested in weak muriatic acid, the lime is dissolved, leaving a great number of thin plates of animal matter, which retain the original shape of the shell. In general, the plates of which these shells are composed are very thin, and closely applied to each other, forming by their union a hard and compact texture.

The pearly or iridescent lustre appears to be confined to shells of this texture, in which it is very general; a circumstance which induces me to believe that this lustre depends in a great measure on the thinness and number of the laminæ of which the shell is formed *.

This variety of structure is found to constitute the whole shell of the *Anomiæ* and *Placunæ*; and to form the inner coat of those shells which have pearly insides, as the *Turbines*, *Haliotides*, *Uniones*, &c., as well as the laminar portion of the *Pinnæ* and Mother-of-pearl shells.

When such shells disintegrate, they separate into very numerous thin lamellar scales of a pearly grey colour and silvery lustre. The Chinese are aware of this circumstance, and use the particles of the disintegrated *Placunæ* as silver in their water-colour drawings. I have myself used some of this silvery powder, brought to England by Mr. Reeves, for the same purpose, in colouring the figures of fish, with good effect: it is not quite so brilliant as the

* The iridescence of the *Turbinella prismatica* and of *Bulimus cactivorus* appears to depend upon the texture of the periostracum.

powdered leaf metal, but it has the advantage of not changing colour by exposure.

In some shells of this structure the layers are thicker, and the animal matter is deposited in larger quantities, giving the shell a foliaceous appearance. In these the calcareous particles are large, opake, white, and earthy, like chalk. This is well exhibited in the common Oyster; and is also found, not so distinctly developed, in the *Pectines*, and on the outer surface of those shells which are internally pearly, such as the *Haliotides*, *Turbines*, &c. The animal matter between the laminæ is sometimes very unequally deposited: it is found forming large brown spots in the pearly coat of many of the *Haliotides*, especially in the *Haliotis Midæ*, and *H. splendens*, in which these spots produce beautiful variations in the colouring and pearliness of the shell.

In many of the fresh-water bivalves there is deposited between the layers of the shell a lamina of animal matter, similar to the periostracum. In the genera *Etheria* and *Mulleria*, such a coat is deposited between nearly all the layers, giving them a very peculiar olive-green colour, and having minute dots on its surface. The shells in question appear to be extremely liable to be eroded by the water, and these successive depositions of animal matter enable them to offer a new layer of periostracum to protect each succeeding plate, as the one above it gives way to the destructive influence of the medium in which they reside. A similar deposit of animal matter is also often found forming green stains in the pearly inner coat of the various species of *Uniones*, and it sometimes protects from the action of the water the inner part of the umbones of shells which have been eroded. In the upper valve of *Ostrea cornucopiæ*, I have observed the thick inner layer to be rather prismatic, and the outer part of the laminæ to be separated by layers of periostracum.

In some shells of this kind, there are left between the plates larger or smaller spaces, which are generally found filled with water. These spaces are sometimes met with in the common Oyster, and they occur not unfrequently in a large *Spondylus*, which is known to the dealers, on this account, by the name of the *Water Spondylus*. In the latter shell it is not unusual to find these cavities, which are sometimes of a large size, in both the valves, recurring one on the top of another, and giving the valve, when cut through, the appearance of a chambered shell; but having no siphon passing from one septum to the other. There

can be little doubt that these laminæ, the concave plates at the end of turreted shells, and the septa of the regularly chambered shells, are all deposited in the same manner, the body representing the model on which they are formed. But it is not so easy to understand why such cavities should be left in these shells, especially in the upper valves, as it is to account for the existence of the analogous structure in turreted and chambered shells, the flat form of their valves enabling the animals of the former, as we might suppose, to extend the diameter of the existing cavity, when larger space was required for their accommodation, without constructing one altogether new. In the *Etheriæ*, cavities in the form of small vesicles, or very thin bladders, are also left between the plates. The cavities in the *Ostreæ*, *Spondyli* and *Etheriæ* are, I have reason to believe, filled with water when the animals are alive; and this also appears to be the case, from Mr. George Bennett's account, with the chambers of the Nautilus; but the water soon evaporates through the pores of the shell, if kept in a dry place. I have never observed this peculiarity except in those bivalve shells which are immediately attached by their outer surface to other bodies.

Many shells are composed entirely either of the rhombic crystalline or of the concretionary structure; but I know only of a single instance (and that occurs in the tube of a shell,) in which the whole mass affects the prismatic crystalline structure. In all other shells of this latter texture, the inner and front part, which is occupied by the body of the animal, is always covered with a coat of the laminar concretionary texture.

4. *On the Power possessed by Mollusca of dissolving Shells, Rocks, &c.*

It has been generally believed, and indeed sometimes most positively asserted, that Molluscous animals do not possess the power of reabsorbing the matter of their shells when once deposited. The following observations, I think, will distinctly prove that this theory is quite unsupported by fact.

If a Cone, an Olive, or any shell whose last whorl almost completely envelopes and protects the rest, and whose cavity is much compressed, allowing only a small space for the convolutions of the body of the animal, be slit down, either from the apex to the front of the axis, or across the body volution, at a little distance before the suture, it will be observed that all the septa between the different whorls are extremely thin and transparent; and when these septa

are minutely examined, they will be found to consist of only a single one of the three plates of which all such shells are originally composed, which plate will be seen to agree in structure with the inner one of the three. On tracing these septa to the outer whorl, it will be observed that every part of them, during the various stages of growth of the shell, has been once a part of the outer whorl; and since we know from experience that the outer whorls of the young Olive and young Cone are as thick in proportion to their size as those of the adult, there is little reason to doubt that each of these septa was originally formed of three plates, in the same manner as the other parts of the shell. That this was actually the case, and that the part remaining is the continuation of the inner plate, the other two plates having been removed by absorption, may be proved by the fact that the other two layers of the same volutions are distinctly visible on the exposed part of the spire, and on the front part near the pillar, while they are deficient only on the thin part of the septa; and if the outer half of the penultimate whorl, or rather the half-whorl just within the mouth, be examined, the two outer layers will be found to be there only in part absorbed, leaving a shelving edge directed towards the cavity of the shell*.

A still stronger instance of the absorption of the septum may be observed in the shells formed by some of those Mollusca whose respiration is effected by means of lungs, as, for instance, the *Auriculidæ*. In the young shells of this family the septa which separate the whorls are incomplete, and twine nearly parallel to each other. As the shells increase in size, the later formed septa become much more oblique and broader, and at length completely separate the cavities of the whorls. When, however, the animals of many of the species, especially those of the *Melampi*, approach maturity, the whole of the septa, except the outer half of the penultimate volution, are absorbed, leaving a simple cavity in the upper part of the shell. On further examining the remains of the septum, it will be found that the absorption has taken place on the outer

* It is probable that some Bernard Crabs have also the faculty of dissolving shell, for it is not unusual to find the long fusiform shells, (such as *Fusus*, *Fasciolaria* and *Turbinella*,) which are inhabited by these animals, with the inner lip and great part of the pillar on the inside of the mouth destroyed, so as to render the aperture much larger than usual. I have never seen this erosion except in dead shells which had been inhabited by Hermit Crabs; but it does not occur in all that are so tenanted, for I have also observed these animals occupying the shells of *Fusi*, &c. in which the lip was in its usual state.

side, as is proved by the surface shelving down to form an acute edge on its inner side.

A similar absorption may be observed in the inner whorls of the *Harpa articulata*; but it is in this case confined to the central part of the septa, and all the coats are partially dissolved, so as to leave a slit between the cavities of the different whorls. An absorption of the upper septum also takes place in some of the *Neritinæ*, as the *Neritina fluviatilis*; and it was on a character derived from this circumstance that De Montfort established the latter shell as a genus under the name of *Theodoxus*.

These facts distinctly show, that as the animal enlarges the mouth of its shell, it absorbs in a greater or less degree the substance of the inner whorls. This process of absorption, besides furnishing the animal with calcareous matter towards the enlargement of its shell, gives more space for the lodgement of the body, and renders the shell far lighter to carry; and these advantages are gained without in the slightest degree detracting from its strength, as the outer whorl and spire, which are alone exposed in shells of this form, remain at least as thick as in most other shells.

In many other univalves, the animal, before depositing the laminæ which form the inner part of the mouth, absorbs the outer layer of the penultimate whorl, as is evidenced by the ridge with which that part is often surrounded. This is particularly the case in the various species of *Turbines*, as in *Turbo coronatus*, *T. smaragdus*, *T. sarmaticus*, and in some *Fusi*, as *Fusus despectus*. But it is most distinct in the *Purpuræ*, where the Lamarckian character of the genus depends upon this absorption, which causes the concave flatness of the inner lip. In the *Murices*, and other shells which have spines or branching appendages on the front of the whorls, the site of which appendages the succeeding whorls must overlap, these processes are generally absorbed by the animal before it produces the inner lip over their base, as their length would otherwise offer an obstacle to the regular progress of the shell. This absorption of the outer part of the last whorl but one, and of the spines, is evidently effected by the edge of the mantle. In specimens taken while the process is going on, there may be observed a notch, formed by this means, in the base of the spines or processes, the completion of which causes them eventually to separate from the shell. A similar effect is produced on a new species of Sun Trochus, *Imperator*

Guilfordiæ, where the keels of the whorls are furnished with a central series of spines, which are removed before the mouth of the shell is continued.

In some shells, however, which have only short processes, as in the variety of the *Pyrula bucephala* with two rows of spines, the front rows are not absorbed, the inner lip being deposited of such a thickness as to cover them. A similar circumstance may be observed in a monstrous variety of *Strombus pugilis*, with two rows of spines, of which there is a specimen in the British Museum.

In the young state of the *Fissurellæ*, the hole by which the fæces pass out of the shell is placed a little in front of its recurved and spiral apex: in this state it has been formed into a genus under the names of *Rimula* and *Puncturella*. But as the animal grows, the hole enlarges in size backwards, and the true apex being absorbed, the hole appears in the adult shell to be placed on the tip, and in some species even to extend behind it.

The animals of many species absorb parts of their shell at regular periods: thus the Tritons, which at each of the periodical interruptions of their growth form a thickened edge to their lips, when they again commence enlarging their shells, generally absorb this thickening both as regards that part which had been deposited on the pillar and that which formed the ribs and teeth of the outer lip; for on examining the cavity of any of these shells, it will be found quite smooth and free from interruption. Such an absorption does not, however, take place in some of the larger *Cassides*, and in the genus *Persona*, in which the thickening of the former lips remains after the shell has enlarged in size, and forms prominent bands on the parietes of its cavity. But a similar periodical deposition and absorption of the thickening of the outer lip takes place in many of the land shells, as the *Helices* and *Bulimi*; in most of which there is formed, at every interruption of their growth, an internal rib, just within the edge of the mouth, which is removed when the animal again begins to increase its shell. This is particularly visible in the genus *Scarabus*, where the interruptions are regularly periodical, each period of growth occupying half a whorl, as in the *Ranellæ*.

Mollusca not only have the power of absorbing their own shells, but they also possess the faculty of forming cavities in those of other animals. When a specimen of *Pileopsis* attaches itself to the surface of a shell, it generally leaves

in the place of its attachment a depression of its own size, and furnished with a horse-shoe-shaped ridge: such cavities are sometimes formed even in other specimens of the same species. It appears moreover to be of little importance how great may be the hardness, or what may be the structure, of the shell on which they fix; all yielding with equal readiness to their absorbing powers. It is not unusual to find holes thus produced nearly a quarter of an inch in depth in the very hard external coat of the larger *Turbines*; and similar depressions are found in *Purpuræ*, *Strombi*, *Fissurellæ*, *Chitones*, *Patellæ*, &c.

The animals of *Siphonaria*, *Patella*, and an allied genus* (*Lottia*), which appears to be peculiar to the coast of South America, have the same faculty, but in a less degree, and the cavities formed by them are destitute of the horse-shoe-shaped ridge. The depressions produced by the *Siphonaria* and the *Chitones* have, however, an unequal groove round their margin, which is largest and deepest on one side, occasioned probably by the shell being generally raised on the opposite side to admit of the access of air to the branchiæ. The *Patella cochlea* is often found at the Cape of Good Hope, where it lives almost exclusively, attached to a large species of the same genus, on the surface of which it forms a flat disk, exactly the size of its mouth. To form these flat disks, (of which there are so generally two, one on each side of the apex of the larger *Patella*, as almost to form a character of the species,) and to assist in the increase of its size, the animal appears also to absorb the coralline or other similar substances with which the larger shells are abundantly covered. The common *Patella* of our own coast, when long adherent to another shell of its own species, to chalk, or to old red sandstone or limestone, also forms for itself a deep cavity of the same form as its shell, and evidently produced by the dissolution of the surface to which it is affixed.

The animals of the several species of *Vermetus*, especially of that called by Daudin *Spiroglyphus*, have the faculty of producing by absorption a groove in the surface of many very hard shells, such as the *Trochi*, *Haliotides*, and *Fissu-*

* This genus must be extremely perplexing to those systematists who attend only to the form of the shell without paying any regard to its animal inhabitant. The shells of *Patella* and *Lottia* do not in the least differ in external form, and yet their animals belong to very different orders, the one having the branchiæ placed round the foot, as in the Chitons, and the other having them placed on the side of the neck, like the *Fissurellæ*, from which indeed it chiefly differs in having only one branchia.

rellæ; which groove they cover with a calcareous deposit, and thus form it into a tube. The history of *Spiroglyphus* is altogether peculiar: the young animal, when first hatched, is covered with an ovate regular spiral shell, consisting of a whorl and a half, and in appearance very like the young shell of *Magilus*, with which, indeed, its affinity is very striking; it soon attaches itself to the surface of a shell, in which it commences the formation of a canal, narrow and shallow in the first instance, but becoming deeper and wider as the animal increases in size. Both the canal and its shelly covering retain for some time the regular discoidal spiral form, and the whorls are sometimes so closely impressed on each other, that the animal actually absorbs part of the tube which it had previously deposited, in order to make room for its new whorl. In one instance which has fallen under my observation, it had left only a very thin transparent plate between itself and the cavity of the tube. When, however, the animal has nearly attained its full size, the shell assumes an irregular form, and is sometimes extended into a straight line, and at others closely twisted over its former shell, which, under such circumstances, it often absorbs. It is not uncommon to find several young animals of this genus burying themselves in the tube of an adult shell.

These unequivocal instances of the power of the Mollusca to dissolve their own shells, and to make holes in the shells of other animals without the exertion of any mechanical force, but by simply applying their foot to the part to be dissolved, afford strong grounds for believing that the holes formed by the regular boring Mollusca, such as the *Pholades*, *Petricolæ*, *Venerupes*, and *Lithodomi*, in shells and calcareous rock, are produced in a similar manner; and this belief is strengthened by the following considerations:

1st. That the animals of most of the boring shells are furnished, like those of which I have just been speaking, with a large foot, more or less expanded at the end.

2ndly. That the holes bored by some of the *Petricolæ* and *Gastrochænæ* are compressed, and so exactly fit the shell, that it would be impossible for the latter to rotate on its axis in such a manner as to use the asperities of its surface for the purpose of rasping, as some conchologists have supposed. I have also seen specimens of *Pholas pusillus*, the back valves of which were so much distorted, as to demonstrate the impracticability of such a process, a

projecting part of the back having evidently been fitted into a cavity on one side of their cell; yet these *Pholades* appeared to have enlarged subsequently to the distortion having taken place. Those of the Barnacles which bore, such as the genera *Conchotrya* and *Brismeus* (and probably *Lithotrya*), form an oblong compressed hole, of the exact size of their shells. Specimens of *Brismeus*, in my collection, are attached to the side of an oyster-shell, in which they have destroyed part of two or three plates to form such a cavity; but although the shells of these boring Cirrhipedes are furnished with raised lamellæ, the projections are placed across the valves in such a manner that no motion that could be given to them would enable them to rasp a hole.

3rdly. That all the boring shells are covered with a periostracum, which is thin in the *Teredines*, *Pholades*, *Laseæ*, &c., and thick in the *Lithodomi*, and which, if the animals used the outer surface of the shell as a means of boring, must be very speedily rubbed off. Such a fact would be readily observed, as this part is never renewed after having been once destroyed; which is easily understood when we consider, that it can only be formed on the edge of the shell before the deposition of the shelly matter has advanced beyond it.

4thly. That although the shells of *Teredines*, *Pholades*, some *Petricolæ*, &c., are covered with short spines and striæ by means of which they might be supposed capable of rasping stones, other boring shells, such as the *Laseæ* and *Lithophagi*, are smooth.

5thly. That I have not observed shells of this kind to bore into any other substances (wood excepted,) than shells, calcareous rocks, clay, marl, chalk, limestone, and sandstone united by a calcareous cement; nor do such shells, as far I have seen on the coast of Devon, attack the latter rock, except when it has lain a long time under the sea, and become as soft as clay. Colonel Montagu states that he has seen specimens of *Gastrochæna* which had bored into fluorspar and granite; but an examination of his specimens in the British Museum proves that what he regarded as fluorspar are merely crystals of carbonate of lime; and although the shell is not uncommon on the coast of Cornwall and Guernsey, I have never seen it produce the slightest impression on the granite rock, even in its disintegrated state. Instead of attempting this, the animal changes its habits, and generally chooses a slight crack in the granite rock, in which it forms for itself, like some of the fossil species of the genus called

Fistulana by Lamarck, a calcareous case, partly constructed of such fragments of shells or stones as may be thrown within its reach. The granite, indeed, appears completely to resist all the dissolving powers of the Mollusca. Thus in some structures, as the Plymouth Breakwater, for instance, in which limestone and granite are employed together, and placed side by side, the *Patellæ* form their rounded holes in the former; while they do not in the slightest degree alter the surface of the latter, except in general by clearing from off it any calcareous substance which may have previously grown upon it. I have one specimen beautifully illustrating this latter fact, a young *Patella* having affixed itself to the shelly base remaining from a Barnacle, in which it has dissolved only the part beneath its foot, leaving the rest forming a ring around its shell.

Many of the boring Mollusca, especially the *Lithodomi* and *Petricolæ*, cover the hinder part of their shells with a calcareous coat, which is often of a spongy texture, and differs from the shell in internal structure. This is probably the dissolved part of the rock again deposited. Many also of these animals, as the *Gastrochænæ*, *Clavagellæ*, and *Teredines*, secrete constantly, and others, as the *Lithodomi*, under particular circumstances, a calcareous deposition, with which they line the inner surface of their holes.

The determination of the existence of this power of dissolving shell and calcareous matter does not, however, remove the difficulty with regard to those shells which bore into wood; although it is not impossible that this substance may also be dissolved by the same means. And this appears to me the more probable, as, although there are some species of *Pholades*, such as *Pholas pusillus* and *P. rudis*, which I have never seen in any other substance, I have found others, such as *P. dactylus* and *P. candida*, indiscriminately in chalk, marl, limestone, red sandstone, and wood; and it is difficult to suppose that these species adopt different means of boring when employed in penetrating the latter substance.

Possessing this power of absorbing their own shells, the shells of other Mollusca, and calcareous rocks, it is remarkable that these animals do not exert it for the purpose of removing extraneous obstacles which may oppose their progress in the formation of their shells. In the collection of the British Museum is a specimen of *Pyrula bezoar* that appears to have grown with perfect regu-

larity until the formation of its last half-whorl, which is thrown considerably more than half an inch out of its proper position by a group of Barnacles. These shells had probably attached themselves to the back of the *Pyrula* at an earlier stage, and, as the latter increased in size, at length filled the place that should have been occupied by the inner lip, which, on meeting with this interruption, diverged from its course, and was thrown over the Barnacles. Had the shell not been taken until a later period, there can be little doubt that the animal would have at length destroyed the Barnacles, and completely hidden them from view, by continuing the whorl entirely over them; although it would appear that it had not the power to remove them by absorption while they retained their vitality. In the same collection there is also a specimen of *Strombus luhuanus* the spire of which has been much distorted in consequence of the temporary attachment of some parasitic shell, which subsequently became loose and has been detached.

In the collection of my friend Mrs. Mauger is a specimen of *Helix aspersa*, showing a similar deformity arising from the same cause; but in this case the obstruction has been produced by a young shell of the same species. The young specimen is attached to the spire, to which it had doubtless fixed itself during the dry season; and not awaking from its torpor so early as its older companion, the latter, when it commenced increasing the size of its shell, threw its new whorl partly over the smaller individual, which was thus inclosed in a prison formed by its own shell. In this instance, the form of the larger specimen is not much altered; but about one half of the young shell projects above the spire.

In like manner, the Cowries, and other shells which have an additional coat deposited on their back by the enlarged lobes of the mantle, on arriving at the adult age, cover in with this coat any body which may be accidentally attached to their surface. There are two specimens of *Cypræa rattus* in the collection of Mr. Gaskoin, on one of which a *Crepidula*, and on the other a Barnacle, is evidently so inclosed; and Humphreys, in the Portland Catalogue, described two specimens of the same shell in which he had observed a similar occurrence. Such accidents appear, however, to be rare, the extension of the mantle having in itself a strong tendency to prevent other animals from adhering to the surface of these shells.

A similar occurrence may frequently be observed in the shells of the genus

Cymbium, the glazed coat of which often includes *Balani* and particles of sand. The presence of such bodies under the glazed coat in these shells is so constant, that I am inclined to believe that the animal deposits this coat with the view of ridding itself of the irritation caused by the adherent sand and Barnacles rubbing against its foot, as the animal of the Chinese Pond Muscle (*Dipsas plicata*) deposits its pearls over buttons or spines which are artificially introduced into its shell.

5. *On the Deposition of Shelly Matter by the Foot.*

It has been very generally supposed, that the calcareous matter of which shells are formed is secreted only by the mantle of the animal; and it has consequently been taken for granted, that the expanded base of the *Cassides* and *Personæ*, the broad inner lip and the closed back of the *Cymbia*, and the polished coat on the outer surface of an *Oliva* or an *Ancillaria*, were each and all deposited by some expansion of the mantle.

I have lately, however, had an opportunity of observing the animals of all these, and of many other genera, in the Museum of the Jardin du Roi at Paris, where my excellent friend Professor De Blainville, who was at that time keeper of this part of the collection, kindly allowed me to examine at my leisure all the stores of Mollusca collected together for a long series of years by the late Baron Cuvier, as well as those brought home by MM. Quoy, Gaimard, and Lesson, from the recent voyages of discovery in which those naturalists took part. At the same time I was allowed, by the kindness of M. Quoy, to consult and copy the numerous drawings made by him, during his voyage, from the animals whilst alive and walking about. From this examination I am enabled to state, that in all the shells just named the shelly matter in question is deposited, and most probably secreted, by the upper surface of the foot, which is very large, and not by the mantle, which, on the contrary, is small, and not expanded beyond the edge of the mouth. This is most obviously the case in the *Cymbia*, *Olivæ* and *Ancillariæ*, which have so large a foot that the shell appears to be actually immersed in it. Animals of these genera, drawn from life, are figured by Adanson in his Voyage to Senegal, and by Forskahl in his Fauna Arabica. The *Murex anus* of Linnæus, which has been referred by Lamarck to his genus *Triton*, differs in this particular from

all the other animals placed by him in that group, and agrees with the genus *Cassis*, the expanded base round the mouth being produced by the very widely expanded foot: it forms the genus *Persona* of De Montfort.

It is remarkable that this fact should not have been before observed, more especially as the operculum of all molluscous animals which are furnished with such a protection is secreted by the back of the hinder part of the foot, where there is no extension of the mantle.

6. *On the Operculum.*

The part usually called Operculum is a horny or shelly plate, adherent to the back of the hinder part of the foot of many Gasteropodous Mollusca. It is always (except perhaps in *Navicella*,) attached to the free end of the large muscle by which the animal is affixed to its shell; by the contraction of which the operculum is brought into such a situation as more or less completely to close the mouth of the shell when the animal is drawn into its cavity. It has hitherto been observed only in those Mollusca which have pectinate branchiæ, and in two genera (*Cyclostoma* and *Helicina*) amongst the pneumonobranchous land shells.

The muscle by which the animal is attached to its shell is generally affixed to the hinder part of the cavity, a little within the mouth: in the long spiral shells, which have a small or moderately sized mouth, it is simple, and forms a single scar on the pillar; but in those which have a large mouth and a slightly developed spire, as *Neritina* and *Nerita*, it is divided into two portions, one attached at each end of the pillar lip; and in those which have the mouth almost as large as the cavity of the shell, such as *Capulus*, it is divided into two nearly equal parts, which extend along each side of the cavity, and form what is generally called a horse-shoe-shaped muscular scar. The insertion of the muscle forms similar scars on the inner side of the operculum. Thus in most opercula there is only a single scar: in those of *Nerita* and *Neritina* there are two scars, one at each end; and in *Capulus* the operculum has a horse-shoe-shaped impression. The only exception, as far as I am aware, to this rule, is in the genus *Concholepas*, where the muscle forms a continuous band nearly round the cavity of the shell, while the operculum, which is very small, is marked only with a single subcentral ovate scar.

By far the greater number of these bodies are formed of a more or less condensed cartilaginous matter, similar to the periostracum; and they are often strengthened by a deposit of calcareous shelly matter on their outer side, or more rarely by a similar deposit of greater or less thickness on their inner surface, in some few instances extending to both. The deposit on the inside may be compared to the glassy enamelled coat which is found in the cavities of certain shells, and that on the outer surface may be considered analogous to the hard enamelled coat covering the backs of the Cowries. A few opercula, such as those of the genus *Neritina*, appear to be truly shelly.

The opercula agree with the valves of shells in being developed on the embryo while included in the egg, and in increasing in size by the addition of new matter round the circumference of the base of the cone of which they are formed: they also agree in the cone being sometimes simple and straight, and sometimes curved into a spiral form. That Adanson regarded them as analogous to the valves is evident from his calling the shells which are provided with these lids on their mouths *Sub-Bivalves*. The principal difference, indeed, between the operculum and the valve of a shell consists in the former having no cavity, the cone of which it is formed being either very much depressed, so as to become nearly flat, or even concave, as in the annular or some subannular opercula, or very much compressed, forming only a spiral ribband, as in the spiral ones. Opercula are never attached to their shells by ligaments or by any other means than that of the adductor muscle; and they are always free, except in the genus *Capulus*, which offers a remarkable anomaly in this part being immediately attached by its outer surface to other marine bodies.

It is proper to observe, that in describing the operculum I have called that the anterior margin, which is nearest to the pillar of the shell, as when the animal is walking this part is directed towards its head; and the right and left extremity are the parts corresponding with the right and left sides of the body. When the operculum is placed in this position, the left end is that which fits into the front, and the right that which corresponds to the hinder part, of the mouth. This distinction of parts may, at first sight, be thought trifling; but to the practical zoologist its importance is very great. The position of the nucleus of the operculum is, for example, almost the only conchological character by which four distinct genera of shells can be divided into groups, although their

animals differ both in external form and in internal anatomy. In the genera *Bithynia* and *Paludina*, which have the nucleus of the operculum nearly central, the animal has short tentacles and no air bag; whilst in *Ampullaria* and *Ceratodes*, which have the nucleus of the operculum on its anterior side, the animals have very long tentacles, and a large air pouch by the side of the branchiæ.

Opercula may be divided into three very distinct kinds, according to their form and manner of growth, and these may be again subdivided according to the mode in which they are covered with various deposits.

The annular operculum may be considered the most simple, the very depressed cone of which it is formed being nearly regular, with the apex more or less central, and the coat of new matter, by which it is increased in size, forming complete rings round its circumference; in which particulars it may be compared to the simple conical shells of the genera *Patella*, *Fissurella*, &c. This kind of operculum does not alter its place in the mouth, and the muscle of attachment only moves nearer towards its anterior edge as the addition of new matter on that side renders such a displacement necessary in order to keep the muscle in its proper situation with regard to the pillar of the shell.

The subannular opercula may be regarded as intermediate between the annular and spiral forms, partially combining the characters of each; but I think it better to consider them apart from the others, inasmuch as they are peculiar to those animals of the Ctenobranchous Mollusca, which are provided with a siphon in front of the mantle for conducting the water to their branchiæ, such as the *Murices*, *Buccina*, *Strombi*, *Melaniæ*, *Melanopsides*, *Aulodi*, and the anomalous genus *Phorus*. They are all of a horny texture, and are characterized by their very depressed cone being somewhat oblique, with its nucleus placed at or near the left end, and the lines of growth forming more or less complete rings around it, but always becoming wider apart from each other as they approach the right side. The left end, towards which the nucleus is placed, is generally acute, and the opposite extremity rounded, which is just the reverse of what takes place in the annular opercula, where the right end is acute and furnished with a fold proceeding from the nucleus, and the left side is rounded and broad. In most of the opercula of this division the muscular scar occupies the greater part of the internal surface; is marked with more or less regular

concentric rings; and is surrounded by a thickened callous deposit, which is broadest on the outer side. This scar appears gradually to approximate towards the right side of the operculum, the part left free, as the scar advances, becoming covered by the callous deposit. The lines on the scar appear to be very constant in the various species, but they are sometimes distorted, and form several centres instead of one. They have no relation to the rings of growth on the outer surface, but have generally a centre of their own placed at some distance from the left end of the operculum; and they appear to be formed by the successive additions made to the edge of the adductor muscle, which is marked with lines resembling those on the scar. The greater number of these opercula do not alter their relative position in the mouth of the shell; but a few, like those of *Fusus fornicatus*, in which the end of the cone is slightly curved, move during their lives perhaps to the extent of a quarter or half a turn on the end of the muscle. In some instances, as in the operculum of *Strombus*, where the foot of the animal is very small, the apex or left extremity is obliquely elevated and free: as the rings of growth are added, this extremity elongates, and acquires such a resemblance in form to the claw of an animal, as to have induced the ancients to call such opercula *Elks' hoofs*. The scar of attachment is small in comparison with the size of the operculum, and is situated on its right side: it is cordate and marked with oblique rugose grooves, and with a strong central ridge, which is continued in the form of a rib down the middle of the under side of the free part of the operculum. In some species the posterior edge of the operculum is serrated. In both the annular and subannular divisions, the disk to which the operculum adheres is formed entirely of the muscle of attachment, and of a membranaceous fringe by which its edge is surrounded. This fringe is free from the back of the foot and is widest posteriorly: it doubtless secretes the coat of the layer of growth, and the deposit which borders the edge of the scar, whilst the muscle itself is provided with the means of secreting the proper coat of the scar.

The spiral opercula are so called because the elongated, cartilaginous or shelly, compressed, ribband-shaped cone of which they are formed is twisted into a spire of few or many whorls. In these, the new matter by which they increase in size is deposited only on the extremity of the last whorl, which in spiral opercula may be regarded as analogous to the mouth of spiral shells, as

the entire circumference of the annular opercula, with their subcentral apex, is analogous to the edge of the base of a *Patella*. The lines of growth are marked by curved concentric lines extending transversely across the whorls. Opercula of this character vary much in the number of their whorls: when the whorls are few in number, the cone increases rapidly in size, and the operculum is of an ovate shape, with the nucleus approximated to the left extremity; when the whorls are more numerous, the cone increases in size more gradually, the nucleus is central, and the operculum is more orbicular. In all these cases the edge of the extremity of the last whorl is constantly anterior, that is to say, when the operculum is in the mouth of the shell, this part of it is directed towards the inner lip: when the operculum is ovate and of few whorls, it generally occupies the whole length of that lip; but in the orbicular and many-whorled opercula, it is directed towards the hinder part of the inner lip, near the angle formed by its junction with the outer. Now every time that the animal adds a new layer on the end of the last whorl, the operculum, to allow of this part continuing to occupy the same position, must make a slight turn backwards on its centre, which is the nucleus of the spire, whether the spire be placed towards one end or in the centre of the operculum. This rotation on the adductor muscle, although it may at first sight appear improbable, bears a striking analogy to several other phenomena of the same kind which are continually taking place in the animal economy: I need only instance two well known and apposite examples;—1stly, the gradual change of situation of the adductor muscle as it passes down the pillar of spiral shells, which in some of the long turreted species, such as *Turritella Archimedes*, where there are as many as thirty whorls, must have been carried to the extent of thirty complete revolutions on this part;—and 2ndly, the change of place of the adductor muscle in bivalve shells. In the opercula of the *Littorinæ* and *Naticæ*, which consist of a few very rapidly enlarging whorls, the motion and consequent alteration of position of the place of attachment is very gradual and slow; but in those orbicular opercula which are composed of many gradually enlarging whorls, as in the *Trochi* and *Monodontæ*, the place of attachment must be continually changing, as many complete revolutions being made as there are whorls in the operculum. These are sometimes extremely numerous: in a small specimen of *Turbo pica* now before me, there are seventeen or eighteen, and in some *Trochi*

I have counted still more. In the spiral opercula, which thus rotate on their axis, the nucleus, which is the centre of motion, is always included in the scar, and adherent to the muscle of attachment: it is often furnished internally with a small spiral process, buried in the muscle and resembling the end of a screw. On the contrary, in the annular and subannular opercula, which have no rotatory motion, the nucleus is often removed from the point of attachment, as is well illustrated in those of the *Strombi*.

In many of those ovate or suborbicular spiral opercula which are formed of a few rapidly enlarging whorls, as, for example, those of the genus *Littorina*, the inner surface exhibits the lines of growth as well as the outer, there being in these cases no internal deposit. In these opercula, the adductor muscle is anterior, and occupies more than half the disk to which they are attached, the remainder being formed by a membranaceous flap attached to the hinder edge of the muscle. Along the whole anterior edge of the muscle is a ridge, separated from it by a deep groove, which evidently secretes the additions to the operculum: in one specimen I thought that I could observe the edge of this part attached to the ridge, in like manner as the edge of the periostracum is adherent to the mantle of many bivalve shells.

The operculum of the *Naticæ* is formed on the plan just described; but its inner surface is covered in addition with a smooth pellucid coat, resembling the inner coat of the subannular opercula, and forming a curved tubercle over the nucleus. This coat is marked with two muscular scars, the one lanceolate and central, and the other anterior, linear, and only separated from the first by a narrow polished band; the latter is extended to the back of the tubercle, where it forms a deep oval impression. The adductor muscle occupies the anterior half of the disk, its middle part, which produces the central scar, being of a dark colour, while its front edge, giving rise to the anterior, is white: it is furnished with a thin membranaceous band posteriorly, which is broadest on the right side; and the remainder of the disk is formed of a thick semioval elevated fleshy flap, quite distinct from the back of the foot.

The opercula of some shells which have plaits on their pillar, are very thin, and are furnished with a moveable flap on the left side of their anterior margin, which passes over the plaits. I first observed this in the common *Tornatella*, and afterwards in *Turbo pallidus* of Montagu, (the genus *Odostomia* of Dr. Fle-

MING,) and have since verified it in *Pyramidella*. The subannular operculum of *Turbinella cornigera* has a notch on the middle of its anterior margin, and a plait running from the nucleus; but in this case the flap is not moveable.

The opercula of the genus *Neritina* agree with those just described, in their ovate form, and in being composed of few and rapidly enlarging whorls; but they appear to be entirely formed of shelly matter, and are marked both externally and internally with very minute concentric lines of growth. Like the operculum of *Littorina*, they are not covered with any internal or external deposit; but they have several peculiarities. The outer edge of their whorls is furnished with a broad flexible margin; and on the inner side, below the spire, are two diverging processes, the longer of which is curved and forms a tooth, placed near the left end of the anterior edge, which some have supposed to act as a kind of hinge on the sharp inner lip of the shell. The adductor muscle of this genus is divided into two portions, one placed at each end of the pillar: of these the hinder is the largest, and forms a submarginal scar along the end of the last whorl of the operculum, while the anterior is smaller, and forms an ovate scar behind the two processes. The disk to which these opercula are fixed is like that of *Littorina*, and there is a slight ridge extending the whole length of the front edge of the muscle, a little anterior to it, which probably secretes the shelly matter of the operculum: in this office it may perhaps be assisted by the edge of the hinder part of the mantle, situated just before it.

I might have been inclined to regard the operculum of *Navicella* as anomalous, had I not had an opportunity of comparing it with its ally *Neritina*, which has enabled me to explain its structure. In this genus, as in *Concholepas* and *Cryptostoma*, the mouth occupies so large a share of the cavity of the shell, and the hinder part of the foot of the animal is so short, that the operculum cannot be folded over in such a manner as to close the aperture. But instead of being very small, as in the two latter genera, the operculum is rather large in comparison with the size of the animal, and appears to serve a new purpose, viz. to separate the viscera from the upper surface of the foot, as the shelly plate does in the genus *Crepidula*. The part which projects externally is very small, and can only be compared to the flexible cartilaginous fringe on the edge of the outer whorls of the operculum of *Neritina*; whilst the shelly

part which is included in the body of the animal is four times the size of the external portion, and appears to represent the anterior margin and the two processes of the operculum of that genus, greatly developed. The anterior process, which appears to be analogous to the curved projection in *Neritina*, is produced into a straight lanceolate ridge, and the posterior into a rounded strongly serrated edge; the straightness of these processes evincing that this operculum does not revolve on its axis.

Other ovate spiral opercula of few volutions have a concentrically ridged inner surface, and their outer surface covered with a shelly coat, which varies in thickness in the different genera, being thin in *Nacca*, *Phasianella* and some *Cyclostomata*, and very thick and convex in the genera *Turbo* and *Imperator*. The disk to which these opercula are attached is like that of *Littorina*; but anterior to the muscle there is a very deep groove, into which the operculum can be pushed, and which probably covers the front part of it like a hood, when the animal is living. I have little doubt that this hood secretes the thick external shelly coat, which is quite out of the reach of the disk, and which increases in size, like the rest of the operculum, by the addition of shelly matter to the edge of its last whorls. That this is really the mode of growth of that part is proved by its being in many cases marked with spiral grooves; while in others the front part of the last whorl is of a different colour from the rest of the operculum, as though it had been covered from the light. It has been sometimes thought that such shelly opercula are attached to the animals by their convex sides; but this is not the case in any of the many specimens that I have examined, in which the opercula were naturally attached to the back of the animal. Some of them have the outer edge of their whorls dilated and free, and occasionally even elevated in such a manner as to form a spiral ridge on the outer side: a structure which may be seen fully developed in the very beautiful operculum of a West Indian Cyclostoma (*Cyclostoma mirabile*, of Woon's Supplement, t. 7. f. 22.).

The operculum of *Nerita* agrees in form with that of *Neritina*; but differs in having no cartilage on its edge, which is furnished, instead, with a groove; in its outer surface being covered with a thick variously formed shelly deposit, as in the genus *Turbo*; and in its inner surface being lined with a thick, callous, polished coat. Between the outer and inner coats there exists a very

distinct concentrically striated horny layer, like the operculum of *Littorina*; and the left muscular scar is deeply grooved, like that of the subannular opercula. This difference in the structure of their opercula forms an excellent distinctive character between these two genera; as do also the differences in the outer surface of those belonging to the genus *Nerita* between various species of that genus. Thus, for instance, the operculum of *N. polita* is smooth, with a transversely grooved marginal band; those of *N. exuvia*, *N. ornata* and *N. chlorostoma* are granular; and that of *N. peloronta* is smooth, with a broad convex marginal rib.

In the orbicular many-whorled opercula of the *Trochi*, the outside, which is generally concave, exhibits the volutions; and the inside is covered with a thick polished coat, marked with curved lines, produced by the successive enlargements of the muscular scar, radiating from the centre to the circumference.

An examination of the animal and operculum of *Trochus Pica* (which from its large size offers a good illustrative example of this form,) having enabled me to understand in what manner those opercula which appear to be the most complicated in their structure increase in size and thickness, I shall proceed to describe its mode of growth. A comparison with those of the other *Trochi* leaves little doubt that they are all formed and increase in size on the same principle.

The disk on the back of the foot of the animal to which the operculum is attached, shows three very distinct parts, viz. 1st, the muscle by which the operculum is affixed, which is semilunar, and occupies nearly the whole of the anterior half of the disk, having its hinder edge thin and membranaceous; 2ndly, an elongated triangular fleshy band, on the right side of its anterior part, which is separated from the muscle by a deep groove; and 3rdly, the back part of the foot, which is raised to the level of the muscle by an elevated border, attached in front to the membranes placed along the sides of the body of the animal, and is marked with minute concentric wrinkles, originating round a longitudinal fissure on its hinder edge, and becoming more and more transverse as they approach nearer to the muscle. This part of the disk merely forms a bed for the operculum to lie upon, without any attachment; it is semicircular, and is prolonged into a narrow process extending up the right

side of the triangular fleshy band. If the inner side of the operculum be examined, it will also be found to exhibit three parts, differing from each other in colour and surface, but agreeing exactly in form with the three parts described as found in the disk: 1st, the scar of the muscle, which is green, and occupies nearly the anterior half of the operculum: 2ndly, on the left of the scar (that is, when the operculum is turned with its inner side towards the observer,) a triangular pale brown spot, occupying the margin of the extremity, and a triangular portion of the last volution: and 3rdly, a black and polished posterior portion.

There can be no doubt, as these divisions of the operculum agree in shape with the three parts observed in the disk, that they are severally deposited by them; and on further examination it appears that the volutions are in fact formed of three coats, each deposited by one of these parts. The new layers are first added to the extremity of the whorls by the small triangular fleshy band placed on the right side of the muscle. Afterwards, as the operculum is moved round in order to present a new end to the influence of the fleshy band, the newly formed part is covered by a black coat, secreted by the process of the back of the foot which extends up the right side of the band. Both these layers are eventually covered by a green coat, which is deposited by the surface of the muscle, and the part of this latter coat which is left exposed as the operculum turns round on its axis, is again covered by a second thin black shining coat, deposited by the posterior part of the disk, or that which is formed of the elevated portion of the back of the foot.

That the spiral opercula actually revolve upon their axes is proved by the manner in which these coats are deposited, as well as by the circumstance that the front edge of the last volution is always directed towards the hinder part of the inner lip of the mouth of the shell,—a position which it could not constantly retain, in conformity with the manner in which these opercula enlarge, without undergoing this revolving motion. A convincing proof that the green coat of the muscular scar which occupies the outer edge of the front part of the penultimate, and the hinder part of the last whorl, has covered all parts of the operculum, except the front half of the last whorl, which in turning has not yet been brought under its influence, may be readily obtained by scratching off the thin black coat, when the green will be found beneath it in all parts

except that last referred to. The surface of the scar itself also demonstrates the fact of the revolution, its hinder edge being raised and definite; while its front edge, which is progressive, is double, the posterior of the two portions being elevated, and the anterior, to which the muscle is just becoming attached, being thin and ill defined.

It has been often supposed that shells which have a toothed mouth never have any distinct operculum; but the exceptions as regards annular or spiral opercula are numerous; thus *Helicina aureola* and *H. depressa*, and all the *Polyodonta*, as *P. clangulus*, &c., have large and regular opercula.

The genus *Vermetus* has an orbicular horny concave operculum, like that of a *Trochus*, but differing in having a large, orbicular, irregularly grooved, muscular scar, placed in the centre instead of on the anterior side. The outer surface in some of the smaller species, as in *V. dentifer** and *V. Adansoni*, is furnished with very close spiral elevated laminæ; but in the large species, as *V. maximus*†, it is homogeneous and horny, and does not exhibit any of the volutions. I have no means of ascertaining whether these opercula revolve, but I am inclined to believe that the spiral ones most probably do.

To these, which every zoologist has been in the habit of regarding as opercula, but the structure of which has not previously been examined in detail, I am inclined to add two other bodies belonging to Ctenobranchous Molluscous animals, which have hitherto been generally regarded as anomalous. The first of these is the support, as it was called by its discoverer M. de France, or under valve, as it has since been regarded by some English conchologists, of the genera *Capulus* and *Hipponyx*. I am induced to regard this body as analogous to the opercula of other spiral shells, because, on an attentive examination of the animals, I find that it is attached in the same situation, and not on the under side of the foot, as most conchologists have supposed; the foot being folded on itself, and the walking disk of other Gasteropodes being in these animals (which never move from the place of their first attachment, and consequently require no such expansion,) represented by a few crumpled folds, placed between the part to which the shelly plate is attached and the head. In this idea I am further confirmed by a somewhat similar structure of the foot in the genus *Vermetus*, where the back of that organ represents a truncated cylinder, filling

* Sowerby, Genera of Shells, Serpula, fig. 6. † Gray, Spicilegia Zoologica, tab. 5. fig. 3, *a*.

up and closing the mouth of the tubular shell. This foot is crowned by a horny operculum, and the walking disk is reduced to a narrow flat band, passing along the front of the cylinder, which band is in some species terminated by two conical processes, situated between that part and the base of the head: the processes have been described as tentacula, which they resemble in form. The shelly plate or operculum of *Capulus* is formed of concentric shelly laminæ, with a nearly central nucleus, and differs from all other opercula at present known, in being immediately attached, by its outer surface, to other marine bodies, like the lower valves of the Oyster and of *Crania*, and thus forming the medium by which the animal is retained in its place. The mouth of the shell being nearly as large as the cavity, the adductor muscle, as in other shells of this form, is divided into two broad bands, forming a horseshoe-shaped, posterior, submarginal muscular scar, and the operculum is marked with a similar impression.

The second body to which I refer is the vesicular appendage, placed on the back of the hinder part of the foot of the animals belonging to the genus *Ianthina**, which appears to assist in floating the animal on the surface of the sea, and probably also in supporting the eggs after the death of the parent. This float, as it has been called, I am inclined, from its being situated in the same position as other opercula, to regard as analogous to those bodies in the neighbouring genera.

In the Medical Repository for 1821, I first called the attention of conchologists to the importance of the characters furnished by the operculum for the distinction of genera and families; and this subject, although almost neglected in this country, has since been pursued with great assiduity by M. de Blainville and other French conchologists. I have fortunately had an opportunity of examining, either in the cabinet of the British Museum or in the Continental collections which I have visited, the animals of the greater number of genera of shells, and have been thereby enabled to determine that the form and structure

* Cuvier at the time of publishing his Anatomy of Mollusca appears to have entertained the same theory, for he there properly describes this body as attached to the hinder part of the foot, a little below the usual place of the operculum; but in his Animal Kingdom he seems to have abandoned it, and describes the animal as having no operculum, but having a vesicular organ under its foot.—Règne Animal, ed. 2. tom. iii. p. 84.

of their opercula offer some of the most constant characters for the distinction and arrangement of families and genera; while, on the other hand, I have convinced myself that systematists have been in the habit of placing too much reliance on the mere fact of their presence or absence as a family character, inasmuch as that circumstance alone will scarcely prove of generic importance. Thus in the genus *Voluta*, the animals of the eight or nine species which I have examined are all destitute of opercula, except *Voluta musica*, which has an operculum of moderate size. The Olives and Mitres are in the same predicament, most of the large species being destitute of opercula, while the smaller species of both genera are furnished with rather large ones, as may be easily seen in specimens of *Oliva eburnea*, *O. zonalis*, or *Mitra striatula*, in which the animals have been dried; and shells in this state are not uncommon in collections. The species of Cones offer in this respect the same variations. These observations will explain the apparent contradictions of describers, and the frequent controversies that have taken place as to whether these and some other genera have or have not opercula. That their presence or absence is not a family character may be inferred from all the genera of *Buccinidæ* being provided with them except *Harpa* and *Dolium*. And this leads me to remark, that many genera and species which have very large mouths, in comparison with others of the family to which they belong, are destitute of, or have very small, opercula, whilst the others have moderate sized or even large ones. Thus the wide-mouthed Cones, as, for example, *Conus geographicus*, have no operculum, whilst the other species have a distinct one: and the genera *Cryptostoma* and *Concholepas* have very small opercula, in comparison with the size of their mouths, whilst the other genera allied to them have their opercula nearly as large as the mouths of their shells. The genus *Vermetus* is in this respect very remarkable: most of the species have the operculum as large as the mouth of the shell; but there is one in the British Museum which has an operculum very small in comparison to the size of the body of the animal, and not one fourth part of the diameter of the tube of shell. Some species of this genus, indeed, are described as having no operculum; and the observation of the above fact induces me to give credit to the description which I was at first inclined to doubt.

But of all the variations in this particular, those of *Capulus* and *Hipponyx*

are the most remarkable: some species appear always to have an operculum, which, like the under valve of *Crania*, differs in thickness according to the form and degree of exposure of the substance to which it is attached:—others, as the common *Capulus Hungaricus*, are generally without operculum, although, according to the observations of Dr. Turton, the last-named species sometimes forms a thin support;—and there are others which, instead of forming an operculum, make for themselves (as has been already alluded to in this paper,) a cavity in the substance of the shell to which they are affixed, which is marked with a lunate ridge, corresponding with the muscular scar of the operculum, and doubtless occasioned by the attachment of the adductor muscle to that part of the shell, which is thus protected from the dissolving power of the mantle.

INDEX

TO THE

PHILOSOPHICAL TRANSACTIONS

FOR THE YEAR 1833.

A.

Acoustic figures, on, 593.
——————— perfect resultant, 596 et seq.
——————— imperfect resultant, 603.
——————— of irregular plates, 604.
——————— of plates of wood, 608.
Amphibia, anterior lymphatic hearts of, 92.
——————— posterior lymphatic hearts of, 89.
Arseniates, phosphates and modifications of phosphoric acid, researches on, 253.
Atomic weights, experimental researches on, 523.

B.

Bakerian Lecture. Experimental determination of the laws of magneto-electric induction, &c., 95.
Barlow (Peter, Esq.). An account of the construction of a fluid-lens refracting telescope of eight inches aperture, and eight feet and three quarters in length, made for the Royal Society by George Dollond, Esq., F.R.S., 1.
——————— On the present situation of the magnetic lines of equal variation, and their changes on the terrestrial surface, 667.
Biphosphate of soda (*second variety of*), experiments on, 271.
——————— (*third variety of*), experiments on, 273.
——————— (*fifth variety of*), experiments on, 276.
Brewster (Sir David, LL.D.). On the anatomical and optical structure of the crystalline lenses of animals, particularly that of the Cod, 323.
Bristol Channel and its rivers, tides of, 208.

C.

CHRISTIE (S. HUNTER, Esq.)—*The Bakerian Lecture.* Experimental determination of the laws of magneto-electric induction in different masses of the same metal, and of its intensity in different metals, 95.

———————— On improvements in the instruments and methods employed in determining the direction and intensity of the terrestrial magnetic force, 343.

Colour, its influence on heat, general remarks on, 285.

——— *on the influence of, on heat and odours*, 285.

——— *its influence on the deposition of dew*, experiments on, 299.

——— *its influence on odours*, general remarks and experiments on, 300 et seq.

Comet of Encke, observations on, 549.

Conducting power generally, facts and observations respecting, 516.

Cotidal lines, essay towards a first approximation to a map of, 147.

———— as determined by the laws of fluids, 149.

———— effect of arms of the sea and bays on, 151.

———— effect of detached islands and groups of islands on, 152.

———— effects of the interference of undulations on, 154.

Crystalline lens of a Cod, number of fibres and teeth in, 329.

———— *lenses of animals, particularly that of the Cod*, on the anatomical and optical structure of, 323.

D.

DAUBENY (CHARLES, M.D.). Note on a paper by Dr. JOHN DAVY, entitled "Notice on the remains of the recent volcano in the Mediterranean," 545.

DAVY (JOHN, M.D.). Notice of the remains of the recent volcano in the Mediterranean, 143.

Dipping needle (Lieut. BARNETT's) *supported by a knife-edge*, remarks on, 354.

Diurnal oscillations in the direction of a horizontal magnetic needle at Malta, on the, 243.

Diurnal variation in the intensity of the force soliciting a magnetic needle suspended horizontally at Malta, experiments on the, 241.

Dreaming, Dr. A. P. W. PHILIP's observations on, 86.

E.

Electric conduction, general remarks and experiments on, 313.

———————— on a new law of, 507.

Electricities derived from different sources, identity of, 23.

———————— ———— Table of the experimental effects common to, 48.

Electricity, common and voltaic, relation of, by measure, 48.

———————— is identical in its nature, whatever be its source, 48.

Electricity by the induction of magnets, on a mode of obtaining an almost continuous current of, 320.
——— *excited in different metals*, on the intensity of, 133.
Electro-chemical decomposition, on, 675.
——— new conditions of, 676.
——— influence of water in, 681.
——— theory of, 682.
Electro-magnets, on certain peculiar properties of, 316.
Electro-magnetism and magneto-electricity, experimental researches in, 313.
Equivalent of lead, 524.
——— of chlorine, 529.
——— of silver, 536.
——— of barium, 537.
——— of nitrogen, 537.
——— of sulphur, 539.
——— of mercury, 540.
Error attributed to M. Ampere, correction of, 53, *note*.
Establishments of places, meaning of, explained, 159.
Experimental researches in electricity (third series), 23.
——— (fourth series), 507.
——— (fifth series), 675.
Experiments (*magnetic*) on Vesuvius, Ætna, and at Gibraltar, 245.

F.

Faraday (Michael, Esq.). Experimental researches in electricity.—Third series, 23.
——— Experimental researches in electricity.—Fourth series, 507.
——— Experimental researches in electricity.—Fifth series, 675.
Field (Mr.), his experiments to determine if the action of the heart be affected by agents making their impressions on the ganglions and plexuses of nerves, 60.
Filters, remarks on the employment of, in chemical analyses, 541.
Fisher (Rev. G.). Magnetical experiments, made principally in the South part of Europe and in Asia Minor, during the years 1827–1832, 237.
Frith of Forth, and its rivers, tides of, 209.

G.

Professor Gauss, *his method for determining the terrestrial magnetic intensity*, remarks on, 357.
Glisson's capsule, &c., of the vaginal portion of, 723.
——— of the interlobular portion of, 729.
Graham (T., Esq.). Researches on the arseniates, phosphates, and modifications of phosphoric acid, 253.

GRAY, (JOHN EDW. Esq.). Some observations on the economy of molluscous animals, and on the structure of their shells, 771.

H.

HALL (MARSHALL, M.D.). On the reflex function of the medulla oblongata and medulla spinalis, 635.

Hearts, four distinct lymphatic, in certain amphibious animals, on the existence of, 89.

Heat, on the absorption of, by differently coloured substances, experiments on, 287.

—— *on the radiation of, by differently coloured substances*, experiments on, 291.

HENDERSON (THOMAS, Esq.). Observations on the comet of Encke, made in June 1832, 549.

Hepatic veins, &c., of the, 733.

HERSCHEL (Sir J. F. W.). Observations of nebulæ and clusters of stars, made at Slough, with a twenty-feet reflector, between the years 1825 and 1833, 359.

I.

IVORY (JAMES, K.H.). On the development of the disturbing function, upon which depend the inequalities of the motions of the planets, caused by their mutual attraction, 559.

K.

KIERNAN (FRANCIS, Esq.). The anatomy and physiology of the liver, 711.

L.

Liver, the anatomy and physiology of, 711.

—— of the lobules of, 713.

—— of the surfaces of, 717.

—— of the portal canals of, 720.

—— of the lobular venous plexuses of, 744.

—— of the lobular arteries of, 747.

—— of the cortical and medullary substances of FERREIN, and of the appearances produced by congestion, 749.

LUBBOCK (JOHN WILLIAM, Esq.). Note on the tides, 19.

M.

Magnetic forces soliciting a horizontal magnetic needle, experiments to determine the relative, 237.

Magnetic lines of equal variation, on the present situation of, and their changes on the terrestrial surface, 667.

Magnetic powers of soft iron, on the, 333.
Magnetical experiments, made principally in the South of Europe and in Asia Minor, during the years 1827–1832, 237.
Magnetism of soft iron, under the immediate inductive influence of an electric current, eminently useful in the formation of artificial magnets, 340.
Magneto-electric induction, experimental determination of the laws of, in different masses of the same metal, and of its intensity in different metals, 95.
Magneto-electric intensity, in different masses of the same metal, on the law of variation of, 101.
——————— in different lengths of the same wire, *ibid.*
——————— in wires of different diameters, 120.
Mars, on the extensive atmosphere of, 15.
Medulla oblongata and medulla spinalis, on the reflex function of, 635.
Metaphosphate of barytes, experiments on, 278.
——————— *of lime*, experiments on, 280.
Mollusca, of the power they possess to dissolve shells, rocks, &c., 796.
——————— on the deposition of shelly matter by the foot of, 805.
Molluscous animals, some observations on, and on the structure of their shells, 771.
Motions of the planets, on the development of the disturbing function, upon which their inequalities, caused by their mutual attraction, depend, 559.
MÜLLER (JOHN, M.D.). On the existence of four distinct hearts, having regular pulsations, connected with the lymphatic system, in certain amphibious animals, 89.

N.

Nebulæ and clusters of stars, observations of, made at Slough with a twenty-feet reflector between the years 1825 and 1833, 359.
——————— Tables of observations of, 365–481.
Nervous and muscular systems in the more perfect animals, on the relation which subsists between them, 55.
North magnetic pole, its position as determined by Captain Ross and Commander JAMES ROSS, coincides with the common point of intersection of Mr. BARLOW's curves of equal variation, 673.

P.

PHILIP (A. P. W., M.D.). On the relation which subsists between the nervous and muscular systems in the more perfect animals, and the nature of the influence by which it is maintained, 55.
——————— On the nature of sleep, 73.
Phosphates and pyrophosphates, of the neutral, 267.
Phosphoric acid, of the modifications of, 280.

Ports, establishment of, meaning of the term explained, 19.
———————— of Brest, Plymouth, Portsmouth, Sheerness, and London Docks, 21.
———————— of St. Helena, 22.

R.

Recent volcano in the Mediterranean, Note on Dr. John Davy's paper on, 545.
Ritchie (Rev. William, LL.D.). Experimental researches in electro-magnetism and magneto-electricity, 313.
River and Gulf of St. Lawrence, tides of, 210.
River Elbe, tides of, 210.
—— *Gironde*, tides of, 210.
—— *Thames*, tides of, 208.
—— *tides*, magnitude of, 203.
———— the bore in, 205.
—— *Waveney*, tides of, 209.
—— *Weser*, tides of, 210.
Rivers, high and low water in, 205.
——— velocity of the tide-wave in, 207.
Ross (Captain), his return noticed, 673.

S.

Shells, first formation of, 771.
—— on the operculum of, 806.
—— the structure of, 789.
—— their external form and variations, 774.
Sleep, on the nature of, 73.
Soda, biphosphate of, experiments on, 270.
Soft iron horse-shoe magnet, account of one that had been made nearly six months, which supported a weight of 100lbs., 337.
Soft iron horse-shoe magnetized by an electric current, experiments to determine the weight it could support, with from one to fifteen thin plates of mica interposed between the poles and the keeper, 339.
South (Sir James). On the extensive atmosphere of Mars, 15.
Stark (James, M.D.) On the influence of colour on heat and odours, 285.
Subarseniate and subphosphate of barytes, experiments on, 264.
———————— *lead*, experiments on, 266.
———————— *lime*, experiments on, 265.
———————— *soda*, experiments on, 253.
Subphosphates and subarseniate of potash, experiments on, 263.
Sulphuret of carbon and crown glass, dispersive ratio of, 6.

T.

Telescope (*fluid-lens refracting*), account of the construction of, 1.
———————————— general principle adopted in the construction of, 5.
———————————— equations to determine the curvature of the lenses of, 6.
Terrestrial magnetic force, on improvements in the instruments and methods employed in determining the direction and intensity of, 343.
Tide observations, causes of inaccuracy in, arise from:—
1. Difference between the time of high water and slack water, 156.
2. Change of the moon's angular distance from the sun in the course of the day, 159.
3. The semimenstrual inequality of the establishment, 161.
4. The correction of the establishment for the age of the tide, 162.
———————— *now extant*, discussion of, 164.
———————— suggestions for making them in future, viz.:—
1. Of the observation of the height and time of tides, 227.
2. On finding the establishment of any place by observation, 228.
3. On the effects of the age of the tide, 231.
4. On the mode of reducing tide observations, 231.
5. On tracing the motion of the tide-wave by comparative observations, 233.
Tides, (*derivative*,) 150.
—— general remarks on the course of, viz:—
1. On the velocity of the tide-wave, 211.
2. On the form of the cotidal lines, 213.
3. On tide-currents running alternately in two opposite directions,—and revolving tide-currents, 215.
4. On the magnitude of tides, 217.
5. On the constancy of cotidal lines, 219.
6. On some peculiarities of the tides, viz:—
Difference of the two diurnal tides, 221.
Single day tides, 224.
Double half-day tides, 226.
—— note on the, 19.
—— *of rivers*, on, 203.
—— *of St. George's Channel*, 179.
—— *of the Arctic Ocean*, 184.
—— *of the Atlantic Islands*, notice of some anomalies pertaining to, 173.
—— *of the British Channel*, 176.
—— *of the coasts of Australia*, 197.
—— *of the Indian Ocean*, 200.
—— *of the North Sea*, 175.

Tides of the Pacific, on the, viz:—
1. Western coast of America, 192.
2. Central parts of the Pacific, 195.
3. Western parts of the Pacific, 196.
—— *of the South Atlantic*, 189.
—— *on the east coast of the Atlantic*, considered, 169.
—— *on the east coast of Great Britain*, 185.
—— *of the West of Ireland*, 181.
—— *on a globe covered with water*, 149.
—— *of the west coast of the Atlantic*, considered, 169.
—— *on the west coast of Scotland*, 183.
—— *on the coast of the German Ocean*, 186.
Turner (Edward, M.D.). Experimental researches on atomic weights, 523.

V.

Voltaic battery, observations on the, so called, poles of, 708.
Volcano in the Mediterranean, notice of the remains of the recent, 143.

W.

Watkins (Mr. Francis). On the magnetic powers of soft iron, 333.
Wheatstone (Charles, Esq.). On the figures obtained by strewing sand on vibrating surfaces, commonly called acoustic figures, 593.
Whewell (Rev. W.). Essay towards a first approximation to a map of cotidal lines, 147.

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METEOROLOGICAL JOURNAL,

KEPT BY THE ASSISTANT SECRETARY

AT THE APARTMENTS OF THE

ROYAL SOCIETY,

BY ORDER OF

THE PRESIDENT AND COUNCIL.

METEOROLOGICAL JOURNAL FOR APRIL, 1833.

1833. April.	9 o'clock, A.M. Barom.	9 o'clock, A.M. Attach. Therm.	3 o'clock, P.M. Barom.	3 o'clock, P.M. Attach. Therm.	Dew Point at 9 A.M. in degrees of Fahr.	External Thermometer. Fahrenheit. 9 A.M.	Fahrenheit. 3 P.M.	Self-registering. Lowest	Highest.	Rain, in inches. Read off at 9 A.M.	Direction of the Wind at 9 A.M.	Remarks.
☽ 1	29.130	48.0	28.968	52.2	46	46.1	54.1	41.9	54.5	0.222	E	A.M. Haze. P.M. Fine and clear. Evening, showers.
♂ 2	29.033	51.7	29.093	52.2	45	49.8	51.1	45.6	51.1	0.161	SSW	A.M. Fog. P.M. Light showers—cloudy.
☿ 3	29.488	52.3	29.594	55.3	50	50.6	57.0	46.4	57.3	0.014	WSW	A.M. Light fog. P.M. Fine—light clouds.
○ ♃ 4	29.521	52.4	29.469	56.7	49	49.4	57.0	44.3	57.0		SSE	A.M. Light rain. P.M. Fine—light clouds.
♀ 5	29.817	54.8	29.917	57.3	42	49.6	55.4	44.3	55.6	0.033	W	Fine and clear—light clouds.—Rain at night.
♄ 6	30.002	54.4	29.942	56.3	39	48.0	55.0	44.1	55.4	0.103	W	Fine—lightly cloudy.
☉ 7	29.857	50.3	29.827	54.3	42	43.3	53.6	38.3	53.8	0.014	NNE	A.M. Overcast—haze. P.M. Fine and clear—light clouds.
☽ 8	29.965	51.1	29.994	54.8	43	47.8	54.7	40.2	55.2		NNE	Fine and cloudless.—A.M. Light haze. P.M. Clear—light wind.
♂ 9	30.108	51.7	30.027	55.3	43	47.7	52.2	39.3	55.1		WSW	Overcast—light haze.—Light rain P.M.
☿ 10	29.857	53.7	29.701	56.4	47	52.8	55.4	45.4	57.3	0.007	WSW	Fine—lightly cloudy.—Showery—light brisk wind P.M.
♃ 11	29.409	53.5	29.315	54.4	41	48.7	51.4	40.8	52.0	0.153	WSW	A.M. Lowering. Noon, hail-storm with thunder. P.M. Clear—cloudy.
♀ 12	29.346	51.9	29.453	53.5	39	46.8	48.8	37.4	51.0	0.133	SW	Lightly cloudy—light unsteady wind. —Light showers A.M.
♄ 13	29.747	51.2	29.687	53.0	36	46.1	51.2	40.3	52.3	0.047	NNE	Fine—light clouds.—Rain at midnight.
☉ 14	29.435	50.7	29.463	52.8	38	44.3	49.2	40.6	50.4	0.044	NNW	A.M. Cloudy. P.M. Fine and clear—light brisk wind.—Hail at 3½ P.M.
☽ 15	29.526	49.7	29.345	51.3	39	46.9	42.6	35.4	50.3	0.111	SSW	A.M. Fine. P.M. Heavy showers.
♂ 16	29.404	47.6	29.467	50.6	36	44.2	46.9	34.0	48.6	0.294	NNE	Lightly cloudy—light unsteady wind. Showers.
☿ 17	29.584	46.8	29.566	49.4	37	42.8	44.3	34.7	48.6		NNW	A.M. Lightly cloudy. P.M. Lowering—light wind—showery.
♃ 18	29.661	46.3	29.720	49.4	37	42.2	49.0	38.3	49.0	0.039	NNE	Overcast.—Deposition A.M.
♀ 19	29.978	49.3	30.011	51.3	36	45.2	51.6	36.6	54.3	0.019	SW	A.M. Fine and cloudless. P.M. Lightly cloudy. Evening clear.
● ♄ 20	30.086	49.4	30.089	53.4	44	48.0	54.8	40.8	55.8	0.019	W	A.M. Light fog—deposition. P.M. Fine and clear.
☉ 21	30.196	51.7	30.187	53.4	40	49.3	53.9	41.3	55.2	0.012	E	A.M. Cloudless. P.M. Overcast.
☽ 22	30.219	51.8	30.196	54.3	42	50.8	58.0	40.7	59.3		W	Overcast.
♂ 23	30.204	52.9	30.162	55.3	44	50.3	58.4	44.7	58.4		N	Overcast—light haze.
☿ 24	30.023	54.6	30.025	57.0	46	52.8	54.2	49.8	56.2	0.008	E	Overcast.—Showers.
♃ 25	30.231	53.3	30.249	54.3	45	49.8	50.2	46.4	50.4	0.014	NE	Overcast.
♀ 26	30.265	54.4	30.208	58.3	44	50.0	61.2	40.2	61.4	0.014	WSW	A.M. Cloudless. P.M. Cloudy.
♄ 27	30.071	58.2	29.994	60.4	53	54.2	60.4	50.3	62.4		WSW	A.M. Light drizzling rain. P.M. Cloudy.
☉ 28	29.764	58.7	29.746	60.4	44	54.6	54.4	50.3	58.3	0.061	WNW	A.M. Fine—cloudy. P.M. Showery. Evening clear.
☽ 29	29.630	56.9	29.562	58.4	42	49.2	55.2	40.3	56.5	0.017	W	Fine and clear.
♂ 30	29.655	56.5	29.645	58.7	39	49.6	56.4	38.7	59.6		W	Fine and clear.
	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Sum		
	29.773	52.2	29.754	54.7	42.3	48.4	53.3	41.7	54.7	1.539		

Monthly Mean of the Barometer, corrected for Capillarity and reduced to 32° Fahr. ..... { 9 A.M. 29.709 } { 3 P.M. 29.682 }

OBSERVANDA.

Height of the Cistern of the Barometer above a Fixed Mark on Waterloo Bridge ..... =83 feet 2½ in.

——————————— above the mean level of the Sea (presumed about)..... =95 feet.

The External Thermometer is 2 feet higher than the Barometer Cistern.

Height of the Receiver of the Rain Gauge above the Court of Somerset House ..... =79 feet.

The hours of observation are of Mean Time, the day beginning at Midnight.

The Thermometers are graduated by Fahrenheit's Scale.

The Barometer is divided into inches and decimals.

METEOROLOGICAL JOURNAL FOR FEBRUARY, 1833.

1833. February	9 o'clock, A.M. Barom.	9 o'clock, A.M. Attach. Therm.	3 o'clock, P.M. Barom.	3 o'clock, P.M. Attach. Therm.	Dew Point at 9 A.M. in degrees of Fahr.	External Thermometer. Fahrenheit. 9 A.M.	Fahrenheit. 3 P.M.	Self-registering. Lowest.	Highest.	Rain, in inches. Read off at 9 A.M.	Direction of the Wind at 9 A.M.	Remarks.
♀ 1	29.435	41.9	29.608	42.3	36	37.2	39.2	32.4	44.7		NW var.	Cloudy—light haze.—Rain at night.
♄ 2	29.971	44.0	28.794	46.7	44	45.3	52.6	34.7	52.6	0.131	SSW	A.M. Rain and brisk wind. P.M. Overcast.
☉ 3	29.041	46.5	29.299	49.4	42	46.3	48.3	41.3	49.0		WSW var	Fine—light clouds and brisk wind.
○ ☽ 4	29.679	46.7	29.768	49.8	44	44.0	54.2	41.3	54.2	0.025	WSW	A.M. Fog—deposition. P.M. Fine—light clouds.
♂ 5	29.875	51.3	29.913	53.8	51	51.2	55.2	43.5	55.2	0.017	SW	Lightly cloudy—light wind—deposition.
☿ 6	30.039	51.9	29.952	54.2	48	48.8	50.7	44.7	51.2		SSW	Fine—cloudy—light wind.
♃ 7	29.823	52.0	29.938	53.8	49	49.4	52.3	46.5	52.3		W	A.M. Overcast. P.M. Cloudless.
♀ 8	29.739	52.6	29.742	55.2	49	50.4	54.3	44.8	54.6		SSW	A.M. Fine. P.M. Cloudy.—At night, rain.
♄ 9	29.660	51.3	29.750	52.5	43	43.1	47.0	42.2	47.0	0.506	SSW	A.M. Light rain and fog. P.M. Cloudless.
☉ 10	29.390	50.4	29.271	52.6	47	47.6	51.8	39.4	52.2		SSW	Rain—brisk wind.
☽ 11	29.420	51.2	29.471	53.3	42	48.2	52.0	46.4	52.3	0.008	SW	Fine—nearly cloudless—light wind.
♂ 12	29.555	50.3	29.645	52.8	44	47.8	50.7	40.7	51.6	0.031	WSW	Fine—cloudy—light wind.
☿ 13	29.353	51.5	29.332	53.2	48	48.2	50.3	45.7	50.6	0.153	W	Cloudy — deposition. — At night, strong unsteady wind with rain.
♃ 14	29.286	50.8	29.475	52.4	42	46.2	48.3	44.3	48.7	0.014	WSW	Fine—light clouds and wind.—At night, rain.
♀ 15	29.160	48.3	29.338	49.4	36	41.1	43.6	37.3	44.6	0.131	NNW	A.M. Cloudy. P.M. Cloudless.
♄ 16	29.657	45.3	29.688	47.7	33	36.6	44.2	33.0	44.2		WSW	A.M. Overcast—light haze. P.M. Cloudless.
☉ 17	29.739	44.7	29.617	47.4	33	39.5	44.1	35.6	44.5		WSW	Overcast—light haze.—Light rain P.M.
☽ 18	29.525	45.8	29.573	48.3	41	41.7	47.5	38.8	47.5	0.028	WSW	A.M. Cloudless—light haze. P.M. Lightly cloudy.
● ♂ 19	29.847	45.3	29.871	48.0	37	40.7	45.6	36.6	46.1		WNW	A.M. Cloudless—haze. P.M. Cloudy.
☿ 20	29.083	48.3	29.080	47.6	40	45.2	44.7	40.2	44.7		SSW var.	A.M. Fine—cloudy—strong unsteady wind. P.M. Light rain.
♃ 21	29.760	46.3	29.917	48.0	42	43.2	45.8	39.8	45.8	0.153	N var.	Overcast.—Light rain P.M.
♀ 22	30.031	45.7	29.998	47.2	40	41.3	42.3	39.6	43.6	0.014	E	Cloudy—light haze and wind.
♄ 23	29.880	43.4	29.798	45.5	35	37.3	42.4	33.0	42.4		NNE	Cloudy—light haze and wind.
☉ 24	29.521	43.2	29.413	44.6	39	38.9	42.3	35.3	42.3		E	Overcast—fog and deposition.
☽ 25	29.571	44.6	29.558	47.2	41	41.2	46.0	37.3	46.3		WSW	Fine.—A.M. Cloudless. P.M. Light clouds.
♂ 26	29.329	47.0	29.202	49.0	45	47.1	49.2	38.8	49.2	0.011	SSE	Cloudy.—Light fog and deposition A.M.
☿ 27	29.097	47.3	29.083	49.3	43	43.5	46.2	41.3	46.2	0.011	ESE	Overcast.—Light rain, morning and evening.
♃ 28	29.287	46.3	28.948	47.5	40	41.0	42.3	35.7	43.7	0.008	SE	Overcast.—Light rain P.M.
	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Sum		
	29.563	47.6	29.537	49.6	41.9	44.0	47.6	39.6	48.1	1.241		

Monthly Mean of the Barometer, corrected for Capillarity and reduced to 32° Fahr. ..... { 9 A.M. 29.510 | 3 P.M. 29.478 }

OBSERVANDA.

Height of the Cistern of the Barometer above a Fixed Mark on Waterloo Bridge ..... = 83 feet 2½ in.

———————— above the mean level of the Sea (presumed about)..... = 95 feet.

The External Thermometer is 2 feet higher than the Barometer Cistern.

Height of the Receiver of the Rain Gauge above the Court of Somerset House ..... = 79 feet.

The hours of observation are of Mean Time, the day beginning at Midnight.

The Thermometers are graduated by Fahrenheit's Scale.

The Barometer is divided into inches and decimals.

METEOROLOGICAL JOURNAL FOR MARCH, 1833.

1833. March.	9 o'clock, A.M. Barom.	9 o'clock, A.M. Attach. Therm.	3 o'clock, P.M. Barom.	3 o'clock, P.M. Attach. Therm.	Dew Point at 9 A.M. in degrees of Fahr.	External Thermometer. Fahrenheit. 9 A.M.	3 P.M.	Self-registering. Lowest.	Highest.	Rain, in inches. Read off at 9 A.M.	Direction of the Wind at 9 A.M.	Remarks.
☿ 1	29.023	46.3	29.162	48.7	38	41.9	47.3	37.3	47.3	0.008	SW	Fine—light clouds and wind.
♄ 2	29.730	45.3	29.810	48.3	36	40.2	48.8	35.3	48.8		WSW	Cloudless—haze.
☉ 3	29.792	49.3	29.742	51.7	44	47.9	52.7	39.7	53.8		S	Fine—light clouds and haze.
☽ 4	29.705	50.0	29.772	52.7	44	47.8	53.8	45.7	54.2		ESE	Fine—lightly cloudy.
♂ 5	30.004	48.3	30.037	51.7	38	39.8	51.9	37.8	51.9		SW	A.M. Cloudless. P.M. Hazy.
○ ☿ 6	30.123	48.7	30.142	49.8	42	43.1	45.4	39.5	45.4		NNW	Lightly cloudy—light wind.
♃ 7	30.273	46.2	30.309	47.3	37	40.7	43.2	36.5	43.3		NNE	Fine—light clouds and wind.
♀ 8	30.291	42.8	30.265	43.5	27	36.2	36.9	32.7	37.3		NNE	Fine—light clouds and wind.—Light snow at 1 P.M.
♄ 9	30.144	39.7	30.041	42.3	33	35.1	39.4	30.2	38.5		NNE	A.M. Light snow. P.M. Fine—light clouds.
☉ 10	29.956	40.3	29.950	42.7	30	37.8	40.4	33.3	40.4		NNE var.	A.M. Overcast. P.M. Fine—light brisk wind.
☽ 11	30.037	39.4	30.039	41.8	34	35.7	39.8	32.3	39.8		N	Cloudy—light wind.
♂ 12	30.045	38.8	29.893	41.0	26	35.8	39.3	33.3	39.3		NNE	Cloudy—light wind.
☿ 13	29.742	39.3	29.590	40.3	25	34.3	37.9	29.4	37.9		ESE	Overcast—light haze.
♃ 14	29.352	37.7	29.295	40.7	24	31.2	38.2	27.8	38.3		E	Cloudless—light haze and wind.
♀ 15	29.389	38.6	29.419	42.6	31	37.2	43.2	29.8	43.2		E	Fine—light clouds and wind.
♄ 16	29.495	42.7	29.451	46.5	41	42.5	46.7	36.5	47.3		E	Light wind.—A.M. Cloudy. P.M. Cloudless.
☉ 17	29.547	43.2	29.566	43.7	36	40.1	39.6	38.7	39.6		ENE	A.M. Overcast—light fog and wind. P.M. Rain.
☽ 18	29.687	42.4	29.752	43.7	40	40.3	40.5	37.2	40.7	0.167	N	A.M. Rain, early. P.M. Overcast.
♂ 19	29.965	41.9	29.980	45.3	35	38.8	44.2	35.2	44.2	0.019	N	Overcast.
♀ 20	30.125	41.3	30.029	44.6	32	36.5	43.5	29.8	43.5		NNW	A.M. Overcast—light wind and haze. P.M. Fine—light clouds.
● ♃ 21	29.877	42.3	29.837	44.7	35	38.8	39.4	32.6	42.3		W	A.M. Overcast. P.M. Cloudless.
♀ 22	29.908	41.3	29.899	44.2	28	36.8	40.7	33.4	40.7		N	Overcast.—Snow at ¾ P.M.
♄ 23	29.914	39.5	29.896	42.4	33	33.0	40.0	28.4	40.0	0.008	N	A.M. Snow early. P.M. Cloudy.
☉ 24	29.934	38.9	29.903	43.3	31	35.8	42.0	30.1	42.0		N	Overcast—light haze.—Evening, light rain and snow.
☽ 25	29.830	41.4	29.780	43.4	38	38.8	42.7	34.8	42.7	0.058	NNE	A.M. Fine—light clouds and haze. P.M. Overcast.
♂ 26	29.850	42.3	29.905	45.3	33	38.4	43.2	3.8	43.2	0.319	S	A.M. Snow early. Fine. P.M. Overcast.
☿ 27	30.076	42.8	30.039	44.6	37	40.4	42.0	34.4	42.0		ESE	A.M. Fine. P.M. Overcast.
♃ 28	30.011	44.3	29.970	48.0	42	42.2	50.2	35.2	50.7		SSE	Fine—light clouds.
♀ 29	29.920	45.6	29.792	49.7	36	42.6	50.9	36.5	51.7		SW	Lightly overcast—foggy.
♄ 30	29.710	47.6	29.728	51.6	40	43.0	50.4	37.7	50.8	0.008	W	A.M. Cloudless. P.M. Cloudy.
☉ 31	29.795	47.8	29.703	51.7	38	43.6	52.7	36.9	53.5		WNW	A.M. Cloudless—haze. P.M. Fine and clear—light clouds.
	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Sum		
	29.847	43.1	29.829	45.7	35.0	39.2	44.1	34.6	44.3	0.587		

Monthly Mean of the Barometer, corrected for Capillarity and reduced to 32° Fahr. ..... { 9 A.M. 29.811 | 3 P.M. 29.784 }

OBSERVANDA.

Height of the Cistern of the Barometer above a Fixed Mark on Waterloo Bridge..... = 83 feet 2½ in.

———————— above the mean level of the Sea (presumed about) ..... = 95 feet.

The External Thermometer is 2 feet higher than the Barometer Cistern.

Height of the Receiver of the Rain Gauge above the Court of Somerset House ..... = 79 feet.

The hours of observation are of Mean Time, the day beginning at Midnight.

The Thermometers are graduated by Fahrenheit's Scale.

The Barometer is divided into inches and decimals.

METEOROLOGICAL JOURNAL FOR JUNE, 1833.

1833. June.		9 o'clock, A.M. Barom.	9 o'clock, A.M. Attach. Therm.	3 o'clock, P.M. Barom.	3 o'clock, P.M. Attach. Therm.	Dew Point at 9 A.M. in degrees of Fahr.	External Thermometer. Fahrenheit. 9 A.M.	Fahrenheit. 3 P.M.	Self-registering. Lowest.	Self-registering. Highest.	Rain, in inches. Read off at 9 A.M.	Direction of the Wind at 9 A.M.	Remarks.
♄	1	30.114	70.9	30.021	69.3	50	70.4	74.3	51.7	76.3		SE	Cloudless.—A.M. Light cloudiness. P.M. Clear.
☉	2	29.746	67.5	29.656	70.4	46	64.8	70.8	60.5	71.6		W	Overcast.—Rain, evening and night.
☽	3	29.537	73.4	29.552	70.6	50	62.7	67.6	53.7	68.2	0.222	SW	Fine and clear—cloudy.
♂	4	29.624	70.3	29.617	69.9	50	62.5	64.3	49.7	68.8	0.014	S	Fine—lightly cloudy.
☿	5	29.756	72.8	29.756	70.0	49	63.8	68.7	50.0	71.2		WSW	Fine—lightly cloudy.—Light shower P.M.
♃	6	29.855	72.3	29.833	70.7	50	67.9	70.7	51.8	72.3		S	Fine—light clouds.
♀	7	30.045	74.0	30.070	72.4	56	67.6	73.5	58.3	74.3		W	Lightly cloudy.
♄	8	30.182	71.3	30.218	72.3	57	65.4	70.4	57.8	72.3		WSW	A.M. Lowering. P.M. Fine—light clouds and wind.
☉	9	30.347	77.3	30.328	73.5	55	68.7	78.0	54.3	79.3		WNW	Fine and cloudless—light airs.
☽	10	30.307	70.6	30.181	73.2	58	65.5	79.5	56.3	80.8		WSW	Fine.—A.M. Cloudless—haze. P.M. Light clouds.
♂	11	29.746	77.8	29.710	73.3	60	68.8	62.8	61.4	70.8		SSW var.	Fine and clear—cloudy—violent high wind.
☿	12	29.778	68.7	29.800	69.8	49	60.3	61.2	52.3	63.6		W var.	Cloudy—light unsteady wind.
♃	13	29.641	64.4	29.497	66.2	53	56.7	59.8	51.7	62.3	0.042	S	Overcast—light rain and wind.
♀	14	29.431	70.6	29.513	67.4	51	60.9	60.8	50.3	66.0	0.056	WNW	Lightly overcast and cloudy.
♄	15	29.891	65.5	29.909	66.0	44	59.2	61.7	46.6	67.7	0.014	E	A.M. Cloudless—faint haze. P.M. Cloudy.
☉	16	29.687	63.3	29.742	67.8	59	59.4	69.9	56.3	70.0	0.208	SSE var.	A.M. Rain. P.M. Clear—cloudy. Evening, clear—light brisk wind.
●	17	29.884	71.3	29.875	69.7	51	65.6	67.2	54.6	69.3	0.056	SSW	Fine—lightly cloudy.—Evening, rain.
♂	18	30.122	73.3	30.130	69.9	54	66.8	70.0	52.8	70.7	0.244	SSW	Fine and clear—cloudy.
☿	19	30.087	68.8	30.027	70.2	53	65.3	66.7	56.7	70.8	0.011	SSW	Lightly overcast and cloudy.—Light rain P.M.
♃	20	29.950	67.7	29.920	70.3	57	61.7	69.9	59.4	71.2	0.031	WSW	A.M. Lightly cloudy. P.M. Fine.
♀	21	30.059	73.7	29.998	71.9	58	66.8	73.3	52.8	74.0		SSW	Fine and clear—light clouds and wind.
♄	22	30.013	76.8	29.978	72.7	50	66.7	67.8	58.3	70.4		W	Fine and clear—cloudy.—Rain, evening and night.
☉	23	29.606	68.0	29.544	70.3	53	60.8	61.8	54.3	66.7	0.514	SSW	Lightly cloudy—shower about noon.
☽	24	29.671	71.7	29.707	68.4	48	61.3	61.8	50.8	67.2	0.083	WSW	A.M. Fine. P.M. Dark and lowering. Thunder and heavy rain at 1¾ P.M.
♂	25	29.945	73.3	29.920	69.8	50	64.1	66.8	48.3	69.3	0.269	SSW	Fine and clear—light clouds.
☿	26	29.804	63.3	29.698	68.8	53	58.7	68.2	52.2	69.8	0.006	NNE	A.M. Cloudy. P.M. Fine.—At 5 P.M. dark and lowering, with light rain.
♃	27	29.737	67.2	29.893	67.8	53	61.7	64.7	55.8	66.8	0.078	SSW	Cloudy—brisk wind—frequent light showers P.M.
♀	28	29.867	68.3	29.759	70.0	55	66.7	73.7	56.4	75.2	0.050	SSE	Fine and lightly cloudy.—Evening clear.
♄	29	29.816	72.7	29.833	71.2	58	68.2	70.3	61.3	71.6	0.011	SSE	Fine and clear—cloudy—light brisk wind.
☉	30	29.954	75.2	29.936	71.9	54	67.6	69.1	57.5	70.3		SSW	Fine and clear—cloudy—light brisk wind.
		Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Sum		
		29.873	70.7	29.854	70.2	52.8	64.2	68.2	54.5	70.6	1.909		

Monthly Mean of the Barometer, corrected for Capillarity and reduced to 32° Fahr. ..... { 9 A.M. 29.754 } { 3 P.M. 29.737 }

OBSERVANDA.

Height of the Cistern of the Barometer above a Fixed Mark on Waterloo Bridge ..... = 83 feet 2½ in.

_____ above the mean level of the Sea (presumed about) ..... = 95 feet.

The external Thermometer is 2 feet higher than the Barometer Cistern.

Height of the Receiver of the Rain Gauge above the Court of Somerset House ..... = 79 feet.

The hours of observation are of Mean Time, the day beginning at Midnight.

The Thermometers are graduated by Fahrenheit's Scale.

The Barometer is divided into inches and decimals.

METEOROLOGICAL JOURNAL FOR JANUARY, 1833.

1833. January.	9 o'clock, A.M. Barom.	9 o'clock, A.M. Attach. Therm.	3 o'clock, P.M. Barom.	3 o'clock, P.M. Att ch. Therm.	Dew Point at 9 A.M. in degrees of Fahr.	External Thermometer. Fahrenheit. 9 A.M.	Fahrenheit. 3 P.M.	Self-registering. Lowest.	Self-registering. Highest.	Rain, in inches. Read off at 9 A.M.	Direction of the Wind at 9 A.M.	Remarks.
♂ 1	30.453	41.2	30.426	42.2	34	34.7	38.0	33.7	42.7	0.088	WSW	A.M. Overcast. P.M. Fine—light clouds.
☿ 2	30.082	43.8	30.031	45.2	43	43.7	46.6	34.3	46.6	0.017	SSW	Strong fog.
♃ 3	30.426	45.0	30.492	45.4	42	41.9	43.0	40.5	43.0		NNE	Overcast—light fog.
♀ 4	30.589	42.7	30.517	42.3	35	36.7	36.5	34.7	36.5		N	Overcast—light haze.
♄ 5	30.386	40.6	30.334	41.5	31	34.4	38.0	30.3	38.0		N	Lightly cloudy—light wind.
☋ ☉ 6	30.455	40.7	30.485	41.4	28	35.0	35.9	29.9	35.9		W	Fine—lightly overcast.
☽ 7	30.589	38.8	30.592	39.8	31	32.6	37.8	29.3	37.8		WSW	Lightly overcast—hazy.—Hoar frost A.M.
♂ 8	30.695	39.8	30.681	40.8	36	36.7	39.0	31.0	39.0		N	Foggy.
☿ 9	30.608	39.8	30.539	39.7	28	34.8	35.8	34.0	35.8		E	Overcast.
♃ 10	30.288	37.2	30.146	37.0	28	28.8	31.7	27.7	31.7		ENE	Fine and cloudless—light haze.
♀ 11	29.928	36.3	29.814	38.7	32	32.2	38.0	27.8	38.0		E	Overcast—hazy.—Hoar frost, A.M.
♄ 12	29.861	38.2	29.838	40.0	34	34.9	39.5	31.5	39.5		ENE	Overcast—hazy.—Rain at night. Hoar frost A.M.
☉ 13	29.909	40.7	29.958	42.3	39	39.3	41.6	34.3	41.6	0.047	E	Fog and deposition.—Light wind P.M.
☽ 14	30.229	42.8	30.213	45.5	41	41.8	41.8	38.6	41.8	0.022	E	A.M. Fog and deposition. P.M. Light rain and wind.
♂ 15	30.192	41.6	30.138	43.2	38	39.1	40.2	35.6	40.2		E	Overcast.
☿ 16	30.211	42.4	30.180	43.7	34	39.6	41.2	36.8	41.2		NNE	Overcast—light haze.
♃ 17	30.164	42.4	30.079	46.0	37	38.1	42.2	36.4	42.7		NNE	A.M. Cloudless—light haze and wind. P.M. Light rain.
♀ 18	30.099	42.4	30.126	43.3	35	37.6	39.7	35.8	39.7		NNE	Overcast—hazy.
♄ 19	30.268	41.5	30.271	42.2	32	36.3	37.9	35.3	37.9		NNE	Overcast—light haze.
● ☉ 20	30.264	41.7	30.313	42.7	36	37.7	36.8	35.6	37.7		ENE	A.M. Overcast. P.M. Clear—lightly cloudy.
☽ 21	30.324	38.4	30.297	39.2	30	36.5	35.8	29.7	36.5		E	Fine and cloudless—light haze.
♂ 22	30.398	36.4	30.426	38.2	25	29.8	35.0	27.8	35.0		ESE	Fine and cloudless.
☿ 23	30.564	36.3	30.566	37.8	27	28.9	36.6	27.3	36.6		E	A.M. Haze. P.M. Cloudless—light haze.
♃ 24	30.479	36.4	30.416	38.7	33	34.0	36.3	27.9	36.3		NNE	A.M. Haze and hoar frost. P.M. Fine and cloudless.
♀ 25	30.237	36.8	30.168	38.2	31	31.7	35.6	29.3	35.6			Overcast—hoar frost.
♄ 26	30.132	38.7	30.110	40.3	34	34.3	39.7	31.1	39.7		W	Overcast—light haze.
☉ 27	30.169	39.6	30.092	42.5	34	34.3	41.2	31.6	41.2		W	Clear and cloudless.—Light haze and hoar frost A.M.
☽ 28	29.982	40.7	29.885	43.6	36	38.2	44.2	33.7	44.2		WSW	Fine—lightly cloudy.—Light wind and haze A.M.
♂ 29	29.427	43.3	29.263	44.0	40	40.2	41.2	37.6	41.2		E	Overcast—light rain.
☿ 30	29.543	43.4	29.663	43.8	38	39.2	39.3	36.8	39.3	0.097	WSW	A.M. Light fog. P.M. Fine light clouds and wind.
♃ 31	29.740	40.8	29.614	41.7	31	33.2	37.0	30.7	37.0		WNW	A.M. Light haze and hoar frost. P.M. Snow.
	Mean 30.216	Mean 40.3	Mean 30.183	Mean 41.6	Mean 34.0	Mean 36.0	Mean 38.8	Mean 32.8	Mean 39.0	Sum 0.971		

Monthly Mean of the Barometer, corrected for Capillarity and reduced to 32° Fahr. ..... { 9 A.M. 30.191 | 3 P.M. 30.154 }

OBSERVANDA.

Height of the Cistern of the Barometer above a Fixed Mark on Waterloo Bridge..... = 83 feet 2½ in.

———————— above the mean level of the Sea (presumed about) ..... = 95 feet.

The External Thermometer is 2 feet higher than the Barometer Cistern.

Height of the Receiver of the Rain Gauge above the Court of Somerset House..... = 79 feet.

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The Thermometers are graduated by Fahrenheit's Scale.

The Barometer is divided into inches and decimals.

METEOROLOGICAL JOURNAL FOR MAY, 1833.

1833. May.	9 o'clock, A.M. Barom.	9 o'clock, A.M. Attach. Therm.	3 o'clock, P.M. Barom.	3 o'clock, P.M. Attach. Therm.	Dew Point at 9 A.M. in degrees of Fahr.	External Thermometer. Fahrenheit. 9 A.M.	Fahrenheit. 3 P.M.	Self-registering. Lowest.	Highest.	Rain, in inches. Read off at 9 A.M.	Direction of the Wind at 9 A.M.	Remarks.
☿ 1	29.703	59.3	29.628	60.2	44	53.3	54.3	43.4	57.7	0.011	SSE	Cloudy.—Light unsteady wind and light rain at night.
♃ 2	29.529	56.4	29.586	58.0	51	53.2	56.7	50.7	57.8		SSE	Light rain, with light brisk wind.
♀ 3	29.824	58.8	29.857	62.8	54	56.5	65.2	50.7	66.3		S	Fine—cloudy.
☾ ♄ 4	29.942	64.6	29.966	67.2	59	63.3	74.3	54.8	75.6		SSE	Fine and cloudless—light haze.
☉ 5	30.300	68.7	30.344	68.8	51	62.3	70.4	57.3	70.4		S	Clear and cloudless—light wind.
☽ 6	30.527	65.6	30.509	68.4	49	60.3	65.0	50.3	70.3		E	Fine and cloudless.
♂ 7	30.441	65.6	30.328	67.2	46	60.3	65.3	48.8	68.0		E	Fine and cloudless.
☿ 8	30.109	60.9	30.006	64.9	53	54.0	65.8	51.6	66.7		E	A.M. Lightly overcast. P.M. Fine and cloudless.
♃ 9	29.851	66.2	29.808	68.7	57	66.2	72.2	52.3	73.4		E	Fine.—A.M. Cloudless. P.M. Light clouds and wind.
♀ 10	29.971	64.3	30.006	67.0	55	58.0	65.6	50.8	66.4		SSW	A.M. Lightly cloudy. P.M. Nearly cloudless.
♄ 11	30.105	62.7	30.095	65.5	52	57.8	66.2	52.2	66.5		NW	Lightly overcast.
☉ 12	30.113	68.9	30.029	69.6	56	65.8	73.8	53.8	75.7		SSE	Fine and clear—light clouds.
☽ 13	30.071	71.3	30.103	70.8	54	67.2	72.4	57.0	73.7		W	Fine—lightly cloudy.
♂ 14	30.246	68.8	30.176	70.3	54	64.2	72.8	53.5	74.3		WSW	Fine.—A.M. Cloudless. P.M. Light clouds.
☿ 15	30.031	72.4	29.950	72.6	55	73.8	79.5	58.4	81.4		E	Fine.—A.M. Clear and cloudless. P.M. Light clouds.
♃ 16	29.950	76.8	29.961	75.3	56	74.2	78.6	63.4	80.3		S	Clear and cloudless.
♀ 17	29.874	76.8	29.901	75.7	59	76.6	79.5	61.2	81.0		ESE	Clear and cloudless.—Evening, light clouds.
♄ 18	30.303	70.3	30.317	73.2	52	60.8	68.3	58.3	69.2		NNE	Lightly cloudy—light wind.
● ☉ 19	30.274	67.3	30.192	66.6	49	61.7	56.3	52.6	64.3		E	A.M. Fine. P.M. Thunder at 5h. 40m. Evening, rain.
☽ 20	30.145	65.9	30.186	70.0	57	61.1	70.0	54.2	71.1	0.361	SSW	A.M. Cloudy. P.M. Fine.
♂ 21	30.422	69.6	30.393	70.4	56	62.2	72.6	53.3	73.7	0.008	WNW	A.M. Cloudless.—P.M. Fine—light clouds.
☿ 22	30.433	71.0	30.384	71.1	57	66.2	71.5	54.2	72.8		E	Fine and cloudless—light haze.
♃ 23	30.428	71.3	30.376	71.2	58	65.8	73.2	52.3	73.4		NNE	Fine and cloudless.
♀ 24	30.348	72.3	30.259	72.0	56	67.7	74.8	52.7	75.7		E	Fine and cloudless.
♄ 25	30.119	74.7	30.026	74.7	51	70.5	75.4	56.9	80.4		SSW	Fine.—A.M. Cloudless. P.M. Lightly cloudy.
☉ 26	30.234	64.6	30.263	67.3	39	55.8	60.4	52.4	61.7		NE var.	Fine—light clouds and wind.
☽ 27	30.344	66.3	30.281	65.8	36	57.2	62.8	47.2	63.4		E	Fine.—A.M. Light clouds. P.M. Cloudless.
♂ 28	30.288	69.3	30.192	68.3	47	62.8	71.7	48.3	71.8		WSW	Fine and cloudless.—A.M. Light haze. P.M. Clear.
☿ 29	30.194	71.3	30.184	69.3	47	62.8	64.2	50.3	65.4		N	Cloudy.—A.M. Fine. P.M. Fair.
♃ 30	30.301	70.3	30.277	67.9	48	61.3	61.3	50.3	64.7		E	Fine.—A.M. Lightly cloudy. P.M. Clear and nearly cloudless.
♀ 31	30.289	69.4	30.234	67.5	45	64.2	68.2	46.3	70.8		E	Cloudless.—A.M. Cloudless. P.M. Clear.
	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Mean	Sum		
	30.152	67.8	30.123	68.7	51.7	62.8	68.7	52.9	70.4	0.380		

Monthly Mean of the Barometer, corrected for Capillarity and reduced to 32° Fahr. ..... { 9 A.M. 30.044 | 3 P.M. 30.012 }

OBSERVANDA.

Height of the Cistern of the Barometer above a Fixed Mark on Waterloo Bridge ..... = 83 feet 2½ in.

——————— above the mean level of the Sea (presumed about) ..... = 95 feet.

The External Thermometer is 2 feet higher than the Barometer Cistern.

Height of the Receiver of the Rain Gauge above the Court of Somerset House ..... = 79 feet.

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